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PROCEEDINGS OF THE

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OF CIVIL ENGINEERS

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CONSTRUCTION DIVISION

Proceedings of the American Society of Civil Engineers

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September, 1959

Papers

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FOUNDATION INSTALLATION REQUIRING RECHARGING OF GROUND WATER[a]

James D. Parsons,[1] F. ASCE

SYNOPSIS

Ground water at the site described, while of assistance in providing, through buoyancy, partial support for the 5 - 14-story structures installed, required special precautions to be taken to safeguard adjacent existing structures, when lowered to permit the new foundations to be installed in the dry. The soil conditions prevailing, the foundation treatment adopted, the proximity of existing adjacent structures and the ground water conditions all have an important bearing on the requirements of the diffusion system described herein which was developed to maintain normal ground water levels in the adjacent areas during the construction period.

INTRODUCTION

In the installation of foundations for structures, it is not infrequent that all or part of such installations are located below ground water level and as a result dewatering is required to permit the work to be carried out in the dry. In lowering the ground water for this purpose, however, it is essential to consider the effect of such operations on adjacent structures, and on occasions the added requirement of maintaining ground water at normal levels in the immediately adjacent areas to protect existing adjacent structures, presents itself. The complications which may arise in accomplishing the latter requirement can be serious, are often costly, and the appropriate solution depends to a large degree on the soil conditions prevailing. The installation described presents a novel approach which was developed to overcome a particularly difficult foundation condition.

Note: Discussion open until February 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2141 is part of the copyrighted Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. CO 2, September, 1959.

a. Presented at the October, 1956, ASCE Convention, Pittsburgh, Pa.

1. Associate Partner, Moran, Proctor, Mueser & Rutledge, Cons. Engrs., New York, N. Y.

General Conditions

The site involved was selected by the New York City Housing Authority for the construction of five fourteen-story middle income apartments to be known as "Coney Island Houses." The project is three blocks in area located immediately adjacent to the boardwalk at Coney Island approximately 150 ft. from the ocean. The buildings, oriented as shown in Figure 1 are among the largest and heaviest in the area and because of the foundation conditions prevailing, had to be supported on heavy buoyed reinforced concrete boxes founded at about Elev. -10, roughly, 10 ft. below mean sea level. To permit them to be installed in the dry, therefore, required lowering the ground water to below Elev. -12 and to accomplish this the contractor elected to install wellpoints, six feet on centers, around the periphery of the three block area. Two intermediate lines were also installed across the project between the north and south main lines to permit flexibility in pumping the construction area. (See Figure 1)

Immediately across 29th St. on the east side of the project is the fifteen-story former Half Moon Motel and the six-story Neptune Apartment House, the foundation conditions under each of which dictated the necessity for the maintenance of normal ground water conditions in their area. Each of these buildings is only approximately 110 ft. from the nearest project Bldg. No. 5. In addition, in a number of the smaller surrounding buildings on the other sides of the project across Surf Avenue and 32nd St. evidence of earlier settlement distress was noted and the influence of lowering the ground water on their performance was a matter of concern.

Soil and Foundation Conditions

Numerous borings of the dry sample, undisturbed and continuous sample types, have been made throughout the area of the site and in adjacent areas, and the principal soil formations encountered are included in the longitudinal geological sections shown in Figure 3. Except for the upper sand layer, the individual formations are uniform in thickness and character within the area. The upper sand layer prevailing between approx. Elevs. +6 and -55, however, was found to contain occasional thin discontinuous layers or lenses of organic silt (mud) up to 2 ft. in thickness and, consequently, in the five NYCHA buildings numerous continuous sample borings were required to establish the integrity of this upper sand layer for the support of the buildings at the locations selected. The settlements in a number of the adjacent existing structures were believed to be due principally to the presence of these organic silt layers and the lowering of the ground water would unquestionably induce further settlements in these buildings. To avoid possible claims for damage which might result, it was considered essential to avoid lowering the ground water in the adjacent areas.

Of principal concern in connection with the foundation requirements for the five Housing Authority buildings constructed was the presence of the two organic silt beds shown in Figure 2 between Elevs. -55 to -80 and -123 and -135. Exhaustive laboratory analyses of undisturbed samples recovered from these beds demonstrated that they have been preconsolidated in the past by the weight of an overriding sand dune to approximately 1/4 tons in excess of the present existing overburden. The estimated distribution of preconsolidation

stresses in the upper silt bed are shown in Figure 3 and the consolidation test pressure-void ratio diagrams from which the individual preconsolidation values were obtained are included in Figure 4. Fourteen-story buildings, if supported on piles or on footings founded at or above normal ground water level would stress these beds well in excess of the maximum stresses to which they have been exposed in the past and, because of the excessively high settlements to be expected they could not be so supported. The influence of foundation level on the ultimate settlements anticipated is shown in Figure 3C. The buildings, therefore, either had to be reduced in height and weight or supported on buoyed reinforced boxes founded at Elev. -10 or lower to provide through buoyancy the necessary reduction in weight on the underlying silt beds. The latter method was selected since the number of additional apartment units afforded by the higher structures were needed. The resulting wellpoint system was provided by the contractor to permit these foundations to be installed in the dry.

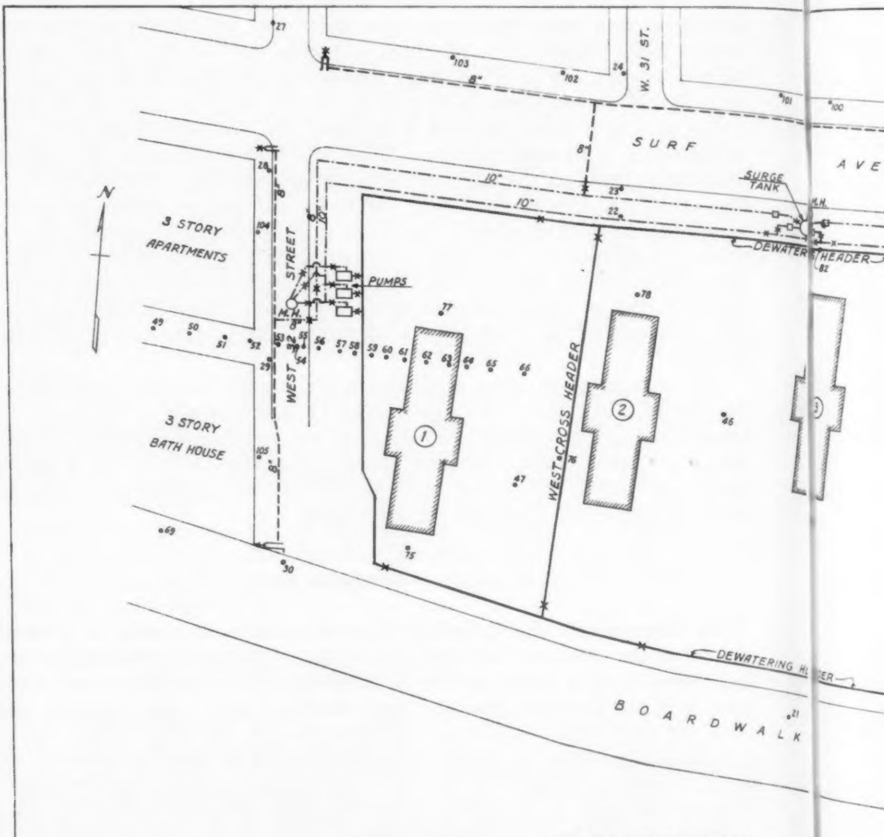
The estimated existing stresses in the organic silt bed under the former Half Moon Hotel which is supported on spread footings in the upper sand layer were computed and found to be close to the maximum preconsolidation stresses in the above mentioned bed. Thus, it became evident that a drawdown of the ground water under this building with the accompanying increase in weight on the organic silt could not be permitted.

Pumping Test

To demonstrate the influence of pumping from the wellpoint system on the ground water levels in adjacent areas and to permit evaluating the problem in this connection, a large number of ground water observation wells within and outside of the limits of the site were installed and a test program, pumping from the west cross header of the system only, (see Fig. 1) was carried out: Continuous pumping from this line for a period of about two weeks, maintaining a drawdown of from -9 to -11 at the header, provided the drawdown information disclosed in Figure 5. The drawdown in this period along an axis roughly parallel with the beach extended back some 1000 ft. from the single line of wellpoints operated, demonstrating that if pumping were carried out from the full wellpoint system which had been installed a very large area would be affected. Towards the ocean, the radius of influence, of course, would be less but in the direction of Surf Avenue a greater influence could be expected. A drawdown to -8 or -9 under the Half Moon and Neptune Apartment at a distance of roughly 90 ft. from the east header was estimated on the basis of this evidence. Therefore, the need for providing facilities to prevent this drawdown under the existing buildings was evident.

Diffusion Test

A number of methods for maintaining the ground water at normal levels outside of the limits of the site during the drawdown period, including the driving of steel sheeting through the upper sand bed into the underlying silt layer and the pumping of water back into the ground by means of a diffusion system located around the periphery of the site, were considered. Cost estimates indicated that the latter method would provide a savings over the other methods and studies for its development were undertaken.



SITE PLAN AND LAYOUT OF
DEWATERING AND DIFFUSION SYSTEM
CONEY ISLAND HOUSES

In view of the limited evidence available regarding the applicability of diffusion methods for installations of comparable size and nature it was decided to first install, as a test section, only a 200 ft. portion of the anticipated ultimate diffusion system located on the east side of W. 29th St. for a test run. This test section, however, was in the most critical area since it was located immediately adjacent to the Half Moon and Neptune Apartment. (See Figure 1) Pumping during this test was from a 100 ft section of the wellpoint system located immediately across 29th Street. The discharge was pumped back into the ground across the street through the diffusion test section. The diffusion system as first installed was much like an ordinary wellpoint system with header pipe, swing joints, riser pipes and wellpoint assembly. Even the diffusion points were fabricated similar to standard dewatering wellpoints except that the points themselves were capped at the bottom and the ball check valve and jet holes omitted. Also instead of utilizing screens approximately

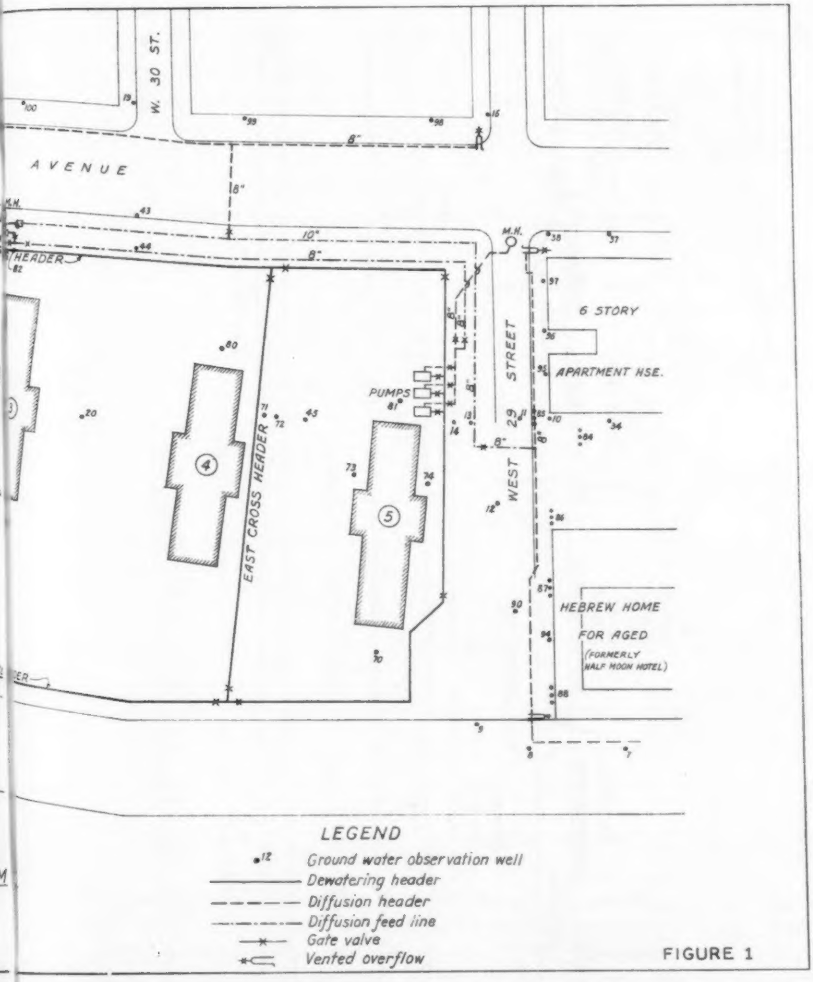
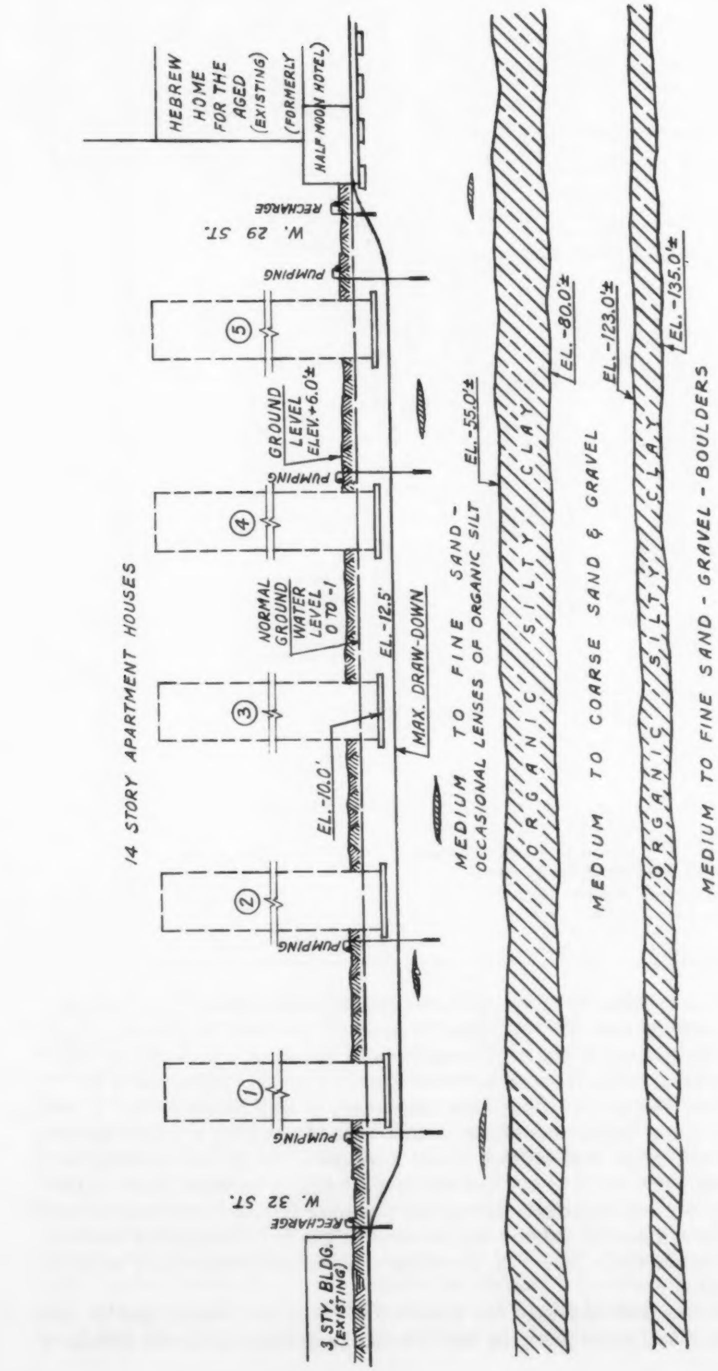


FIGURE 1

3 ft. in length as ordinarily provided in wellpoint installations the diffusion points were made up with 8'3" screens to provide adequate discharge area. The diffusion wellpoints in the test section were jetted into position on 4 ft. centers, with the screens located between Elev. -1 to -9. While the 4 ft. spacing was first felt to be closer than necessary it was believed that it would more readily permit experimentation in this connection than a wider spacing.

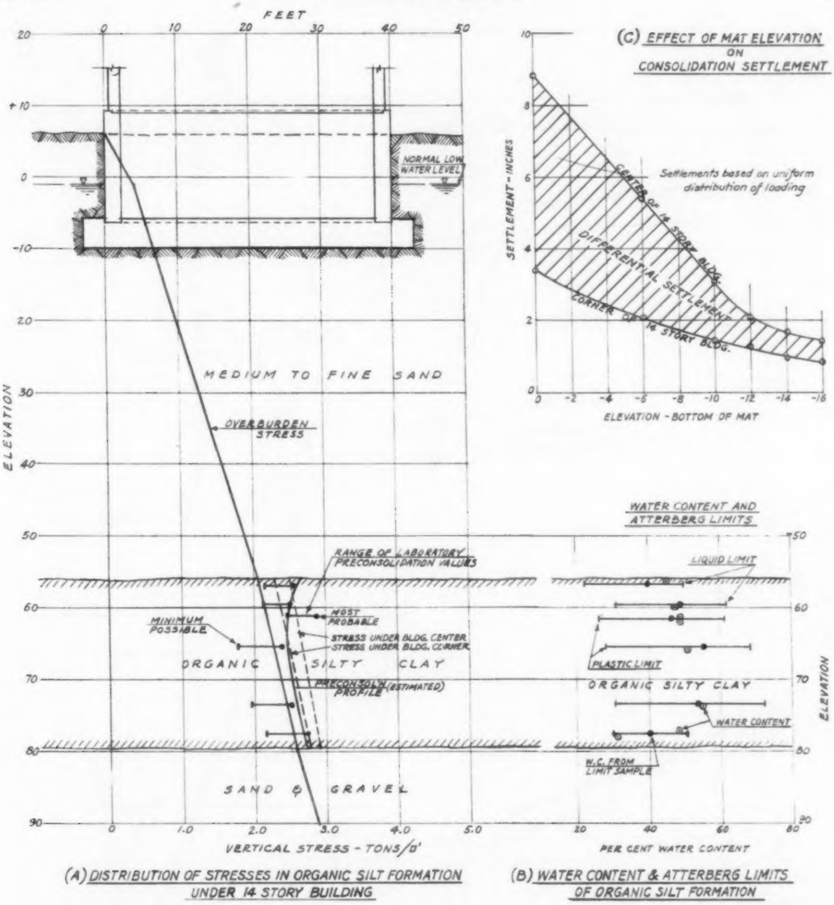
Before operating the test section detail surveys of all of the existing buildings in the area were carried out and settlement points on them were established for periodic observations during the pumping period. Provisions were also made to obtain hourly ground water level in the early stages in each of the 135 observation wells (See Fig. 1) which were established in the area for control purposes.

The test section was operated for a period of about two weeks and by careful control of the wellpoint pumping and discharge pressures in the diffusion



LONGITUDINAL SECTION THRU PROJECT

FIGURE 2

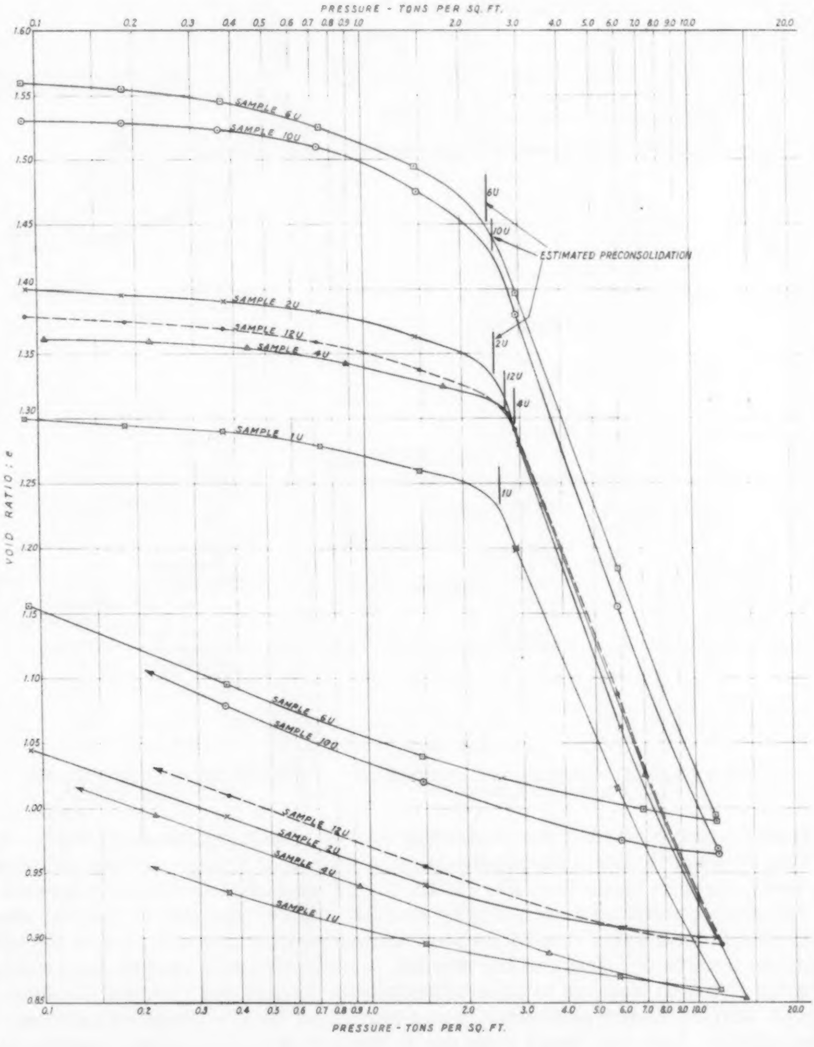


(A) DISTRIBUTION OF STRESSES IN ORGANIC SILT FORMATION UNDER 14 STORY BUILDING

(B) WATER CONTENT & ATTERBERG LIMITS OF ORGANIC SILT FORMATION

FIGURE 3

system readily attained the desired drawdown conditions shown in Figure 6. This flow net is drawn perpendicular to the lines of dewatering and diffusion points, through Wells Nos. 84, 85, 10, 11, 12, 13 and 14 and closely approximates the conditions anticipated by earlier studies. Normal or slightly above normal ground water conditions were maintained for a major part of the test period outside the limits of the site but, during the latter stages, the pressure in the diffusion line had to be substantially increased and in some instances even with the higher pressures it was found that the discharge was almost negligible. This was found to be due to the accumulation, predominately, of a precipitate of ferrous hydroxide Fe (OH) 2 or active rust in the diffusion points which may in part, have resulted from insufficient prior clearing of the lines. This compound forms largely from the galvanic action between the various metals in the system. It is voluminous, gelatinous, and colloidal in particle size so that it cannot be readily filtered. It was realized, therefore, as a result of the test section, that in order to provide the diffusion protection needed in the final installation for the several months' period required



PRESSURE-VOID RATIO DIAGRAMS
ORGANIC SILTY CLAY FORMATION
BORING UD-1

FIGURE 4

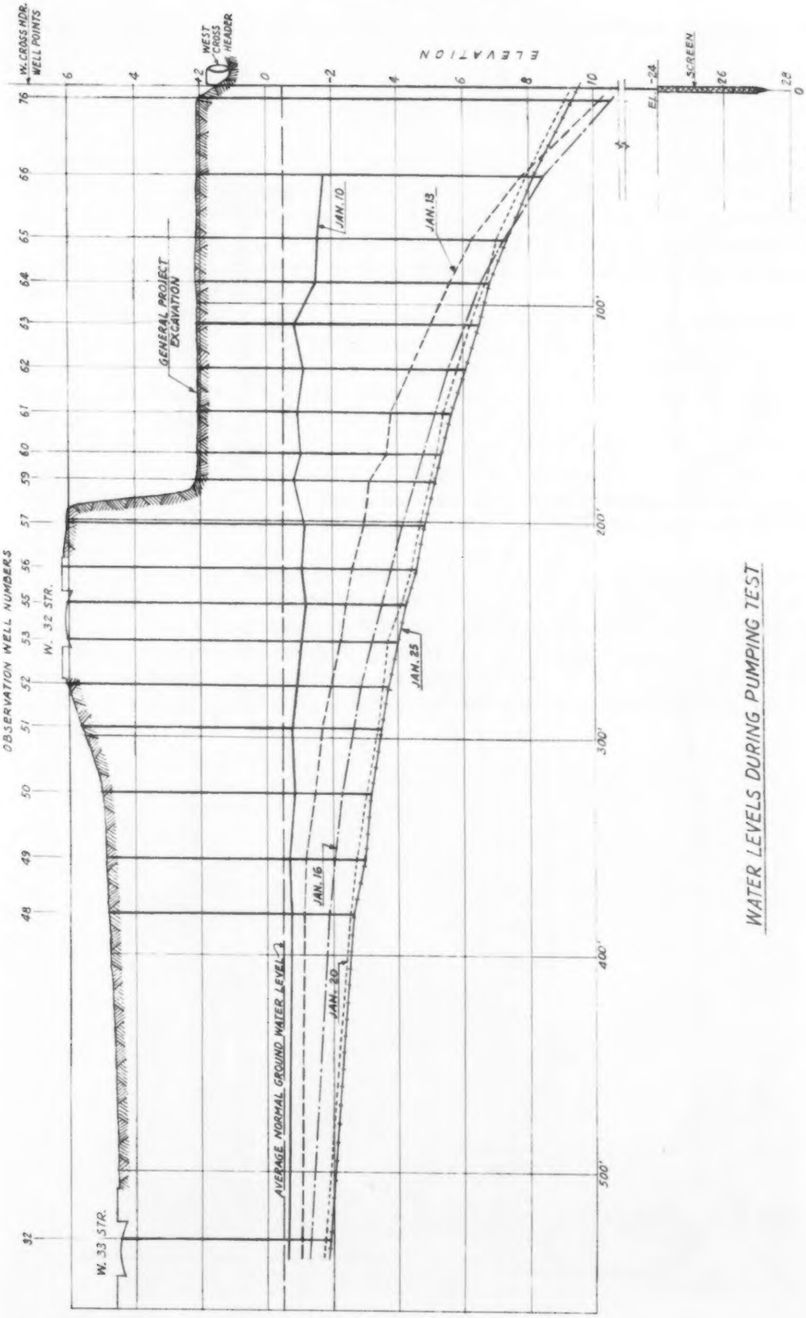
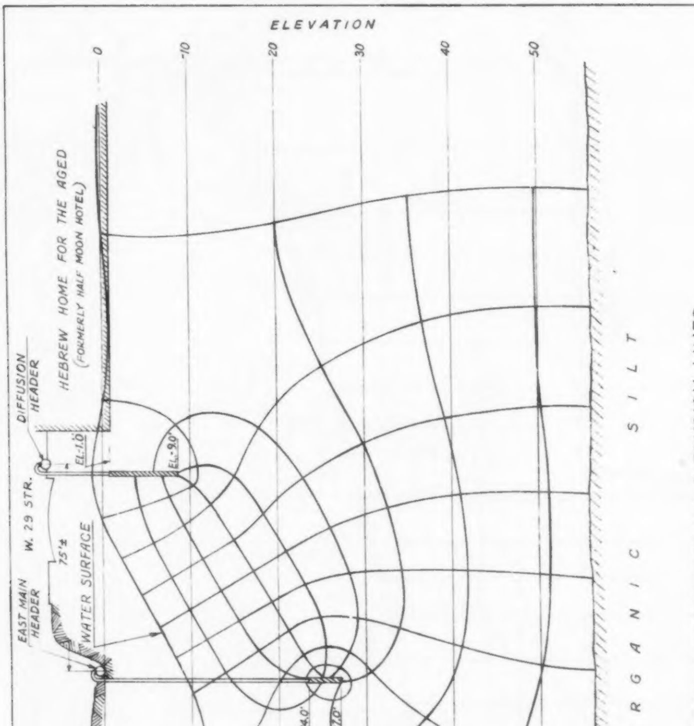


FIGURE 5

WATER LEVELS DURING PUMPING TEST



FLOW NET THRU EASTERLY DRAWDOWN AND DIFFUSION LINES

FIGURE 6

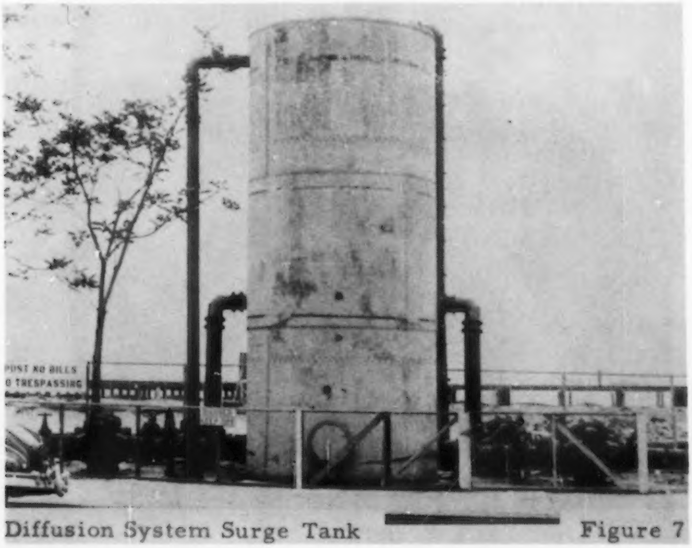
for the foundation installation, facilities to overcome this difficulty had to be developed.

Final Diffusion Protection Provided

In developing the plans for the final diffusion system, analyses of the ground water and of samples of the precipitate from the test section screens were carried out. These analyses indicated the need for limited cathodic protection and filtering facilities. Because of the critical and complex nature of the problem a corrosion consultant was engaged and his recommendations were incorporated in the design.

The final diffusion system was operated principally from one battery of pumps located on W. 32nd St. although an auxiliary set of pumps was provided on W. 29th St. for emergency purposes. The diffusion system extended around three sides of the site on the opposite sides of W. 29th St., Surf Avenue, W. 32nd St. from the main dewatering system, as shown in Figure 1. The header line for the diffusion system was 8" in diameter and the diffusion wellpoints were spaced along its length on 4 ft. centers. A 10'6" diameter steel surge tank, 25 ft. in height was installed at approximately the center of the north property line to provide a constant controllable head on the diffusion system. (See Figure 7)

Discharge water from the wellpoint system was pumped through a 10" dia. feeder line to the surge tank and from the tank it was distributed at low pressure across Surf Avenue, 29th and 32nd Streets in 8" dia. lines to the diffusion headers. The excess from the dewatering system as well as the surge tank overflow was wasted into the existing storm sewer. Along the diffusion header and feeder lines were installed gate valves, piezometers and

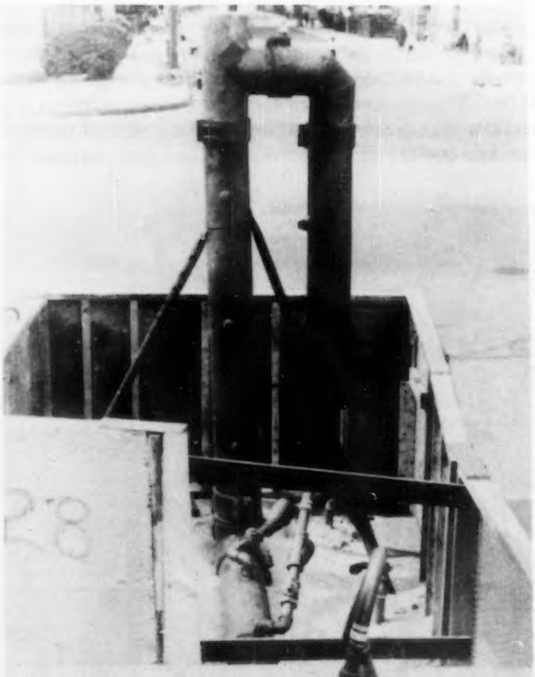


Diffusion System Surge Tank Figure 7

pressure gauges to further regulate the pressures. The maximum pressure in the diffusion header at the ends of the lines was maintained at 3 lbs. per sq. in. by 7 ft. high vented overflow loops (See Figure 8), and the pressure drop between the surge tank and the ends was 7 lbs. per sq. in. In the 1600 feet of diffusion system installed there were approximately 400 diffusion points. The main dewatering system, on the other hand, which was roughly 2400 ft. in length had an equal number of wellpoints. In the two cross headers there were about 70 additional points. As in the test section, the diffusion wells were jetted into position with their screens located between roughly Elev. -1 and -9. The dewatering point screens, on the other hand, were between Elev. -24 and -27 as shown in Figure 6.

Cathodic Protection

In accordance with the recommendations of the corrosion consultant, a limited cathodic protection system was installed, the inside walls of the diffusion feeder and header piping were coated with a special vinyl paint and the diffusion riser pipes were galvanized and coated. The cathodic protection involved the installation of one inch diameter zinc rods at intervals of from 4 to 6 ft. along the header pipes. This was considered necessary to retard the



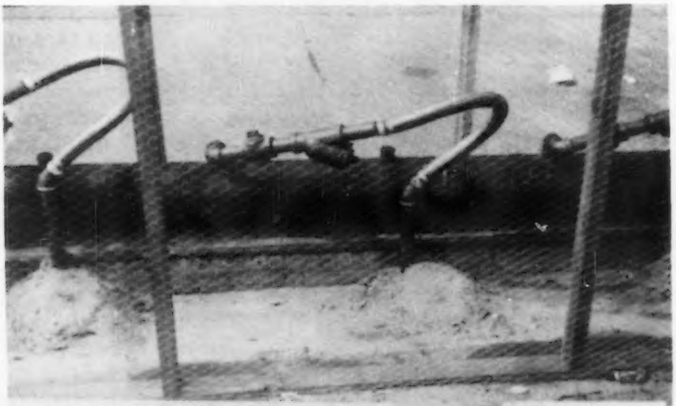
Vented Overflow Loop Figure 8

galvanic action between the various metals in the system. A similar cathodic protection was provided in the surge tank. In order to ascertain the degree of zinc in the system during the operations reference electrodes were installed at a number of locations along the lines and potentiometer readings were taken periodically for review by the corrosion consultant. A study of the potentiometer readings permitted monitoring the level of zinc dissipation and this was essential since too high a level of dissipation could produce undesirable hydroxides which might clog the diffusion filters.

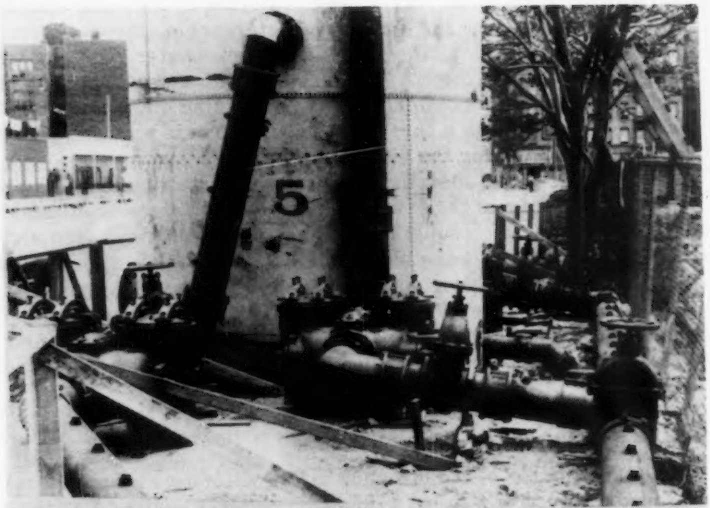
In addition to the above described measures, the galvanized diffusion riser pipes were separated from the brass screens by insulators to eliminate the development of an electric couple between the two metals involved and individual 100 mesh screens were installed in each of the swing joints between the headers and risers to filter out insoluble matter passing through the system. (See Figure 9) Large 50 mesh screens were also provided on both the inflow and outflow sides of the surge tanks as shown in Figures 10 and 11a. Frequent cleaning of all screens was required in spite of the cathodic protection provided.

Operation of System

As it was the function of the diffusion and dewatering systems to maintain normal ground water levels in the areas immediately surrounding the site while lowering the levels within the construction area, in the initial stages of its operation the balancing of one system against the other was of principal concern. Of particular significance in this connection was the fact that the quantity of water diffused into the ground is principally a function of the pressure in the water at the diffusion wells. Such pressures, in all cases, had to be limited to those associated with the development of a quick condition in the soil surrounding the points. Flooding or a quick condition, however, could be readily detected when it occurred and throttling of the swing joint valve at the location permitted immediate correction.

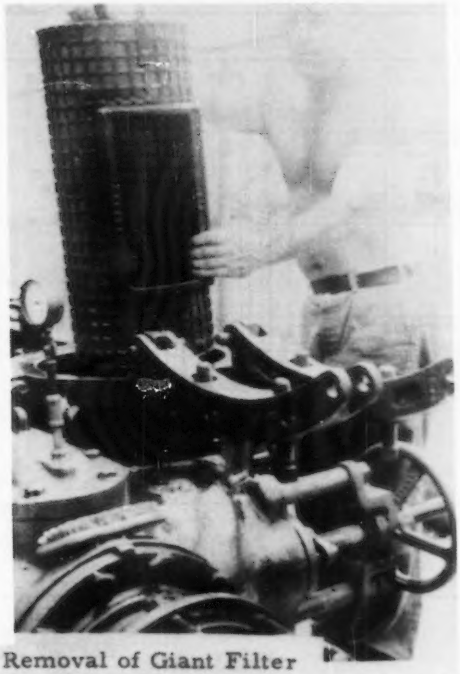


Individual 100 Mesh Filter Figure 9



Giant Filters at Surge Tank Figure 10

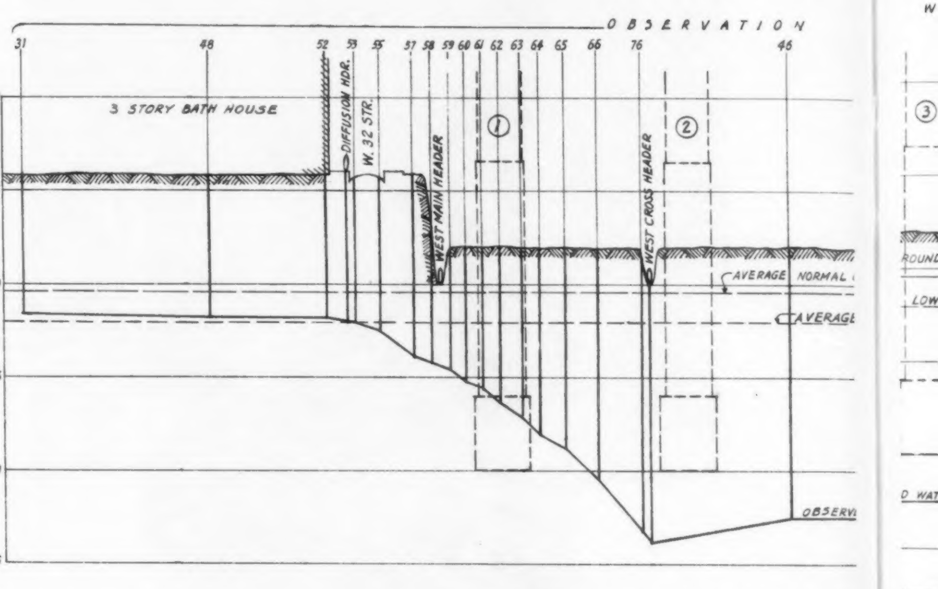
Close-up of Giant Filter Figure 11a



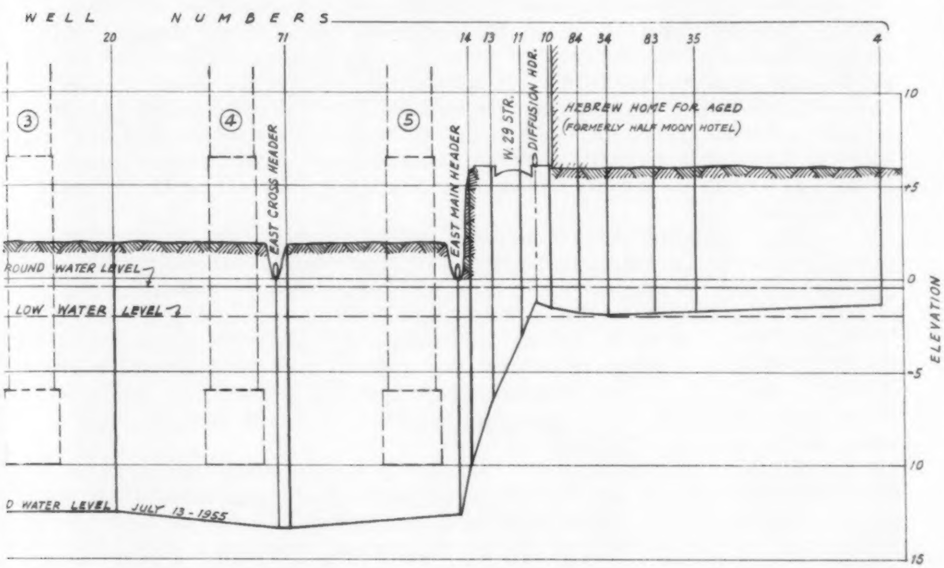
Removal of Giant Filter at Surge Tank Figure 11

The system was balanced in the initial stage so that the surge tank was maintained full, up to the overflow pipe with the feeder and diffusion line valves adjusted so that pressures in the diffusion header lines averaged less than 3 lbs. per sq. inch. The New York City Housing Authority assigned observation teams on an around-the-clock basis during the early stages to record the drawdown and diffusion levels indicated in the 135 observation wells established within and outside the limits of the site (See Figure 1). These observations were plotted and the ground water levels contoured on a continuous basis. Adjustments in the system were made several times each day during the early stages and with an average pressure of 3 lbs. per sq. in. normal water levels were able to be maintained outside the site. The water pumped by the wellpoint dewatering system was initially 6000 g.p.m. reducing ultimately to about 4500 g.p.m. in the final stages of which roughly 3000 g.p.m. were diffused into the ground and the rest wasted.

The full system shown in Figure 1 was operated between late June through September and the foundations of the five buildings constructed were installed during this period. While a maximum drawdown to Elev. -12.5 over the entire site was not required at any one time. This drawdown was maintained over a major part of the area during the later stages when work on four of the foundations was being carried out simultaneously and the drawdown curve for this period is shown in Figure 12. Note the normal levels maintained outside



MAXIMUM DRAWDOWN AND DIFFUSION W



ATER LEVELS DURING FOUNDATION INSTALLATION

FIGURE 12

the limits of the site. An aerial view of the site showing each of the several building foundations in varying stages of construction during pumping is shown in Figure 13.

While the final diffusion system provided the protection needed under the existing adjacent structures it was not completely devoid of operating difficulties since, after a limited period of operation, new gelatinous substances began to again collect at the filters. In spite of the fact that chemical and biochemical analyses of the material indicated the possibility of a multiplication of bacteria in the system antibacteriological treatment was not adopted because of the limited period of operation remaining and instead regular backflushing of the diffusion wells was carried out. Frequent cleaning of the filters also was required.

After the completion of the foundations and subsequent to the dismantling of the diffusion and dewatering systems, a detailed check of all of the buildings surrounding the site was again made and this showed no evidence of settlement or movement and no damage to the buildings attributable to the lowering of the water table. During and subsequent to the construction of the Housing Authority buildings settlement observations were carried out on each of the five buildings and the settlements have been noted to be within the predicted limits computed. A typical set of observations for Building No. 3 are included on Figure 14.

The diffusion system described is believed to be the first of its type to be developed. While it definitely served its purpose and shows great promise of providing a valuable and practical solution to problems of a similar nature, in any specific case, the soil and ground water conditions must first be adequately determined before its applicability can be established.

ACKNOWLEDGMENTS

The dewatering and recharging operations described in this paper were carried out at the site of New York City Housing Authority's Coney Island Houses and the observations reported upon were obtained by the Authority's staff on the project. Moran, Proctor, Mueser and Rutledge, Consulting Engineers, advised the Authority on all phases of the foundation work and provided field supervision during the dewatering and diffusion operations. Structural engineers for the Authority were Di Stasio and Van Buren. The design and installation of the dewatering and diffusion systems was carried out by the Griffin Wellpoint Corporation.

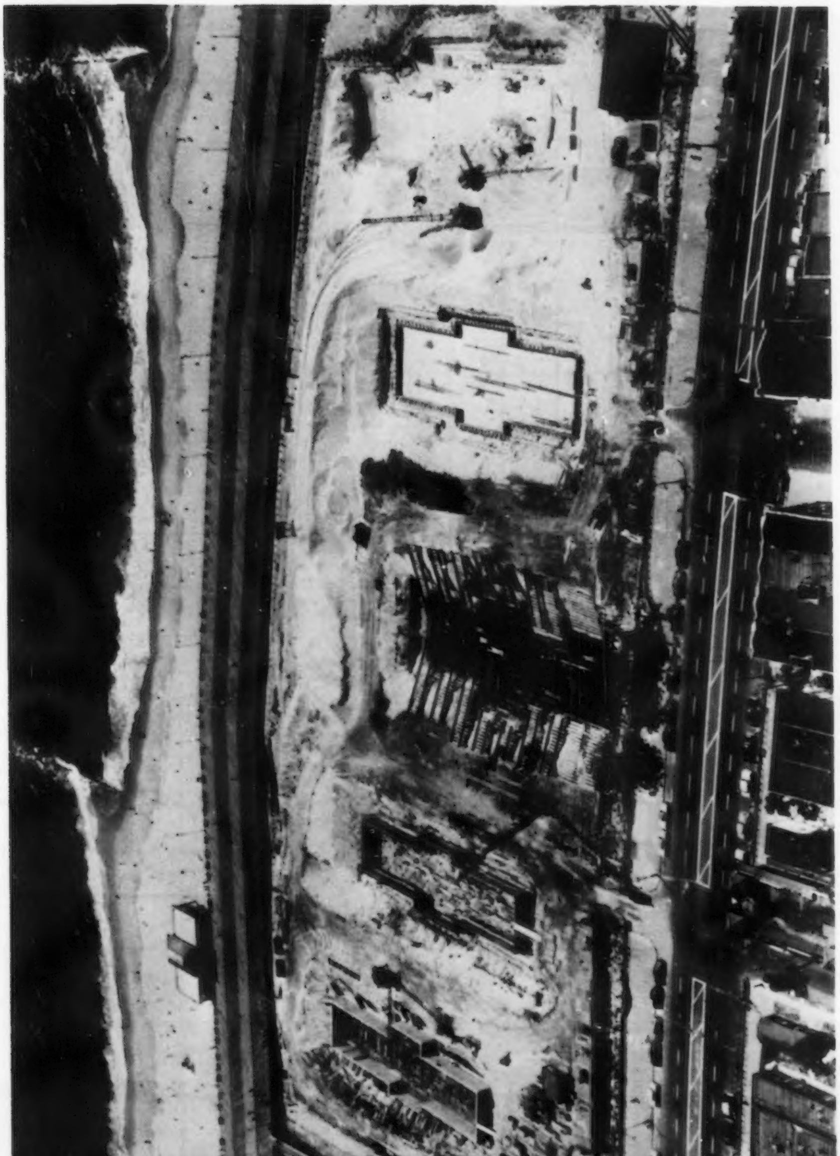
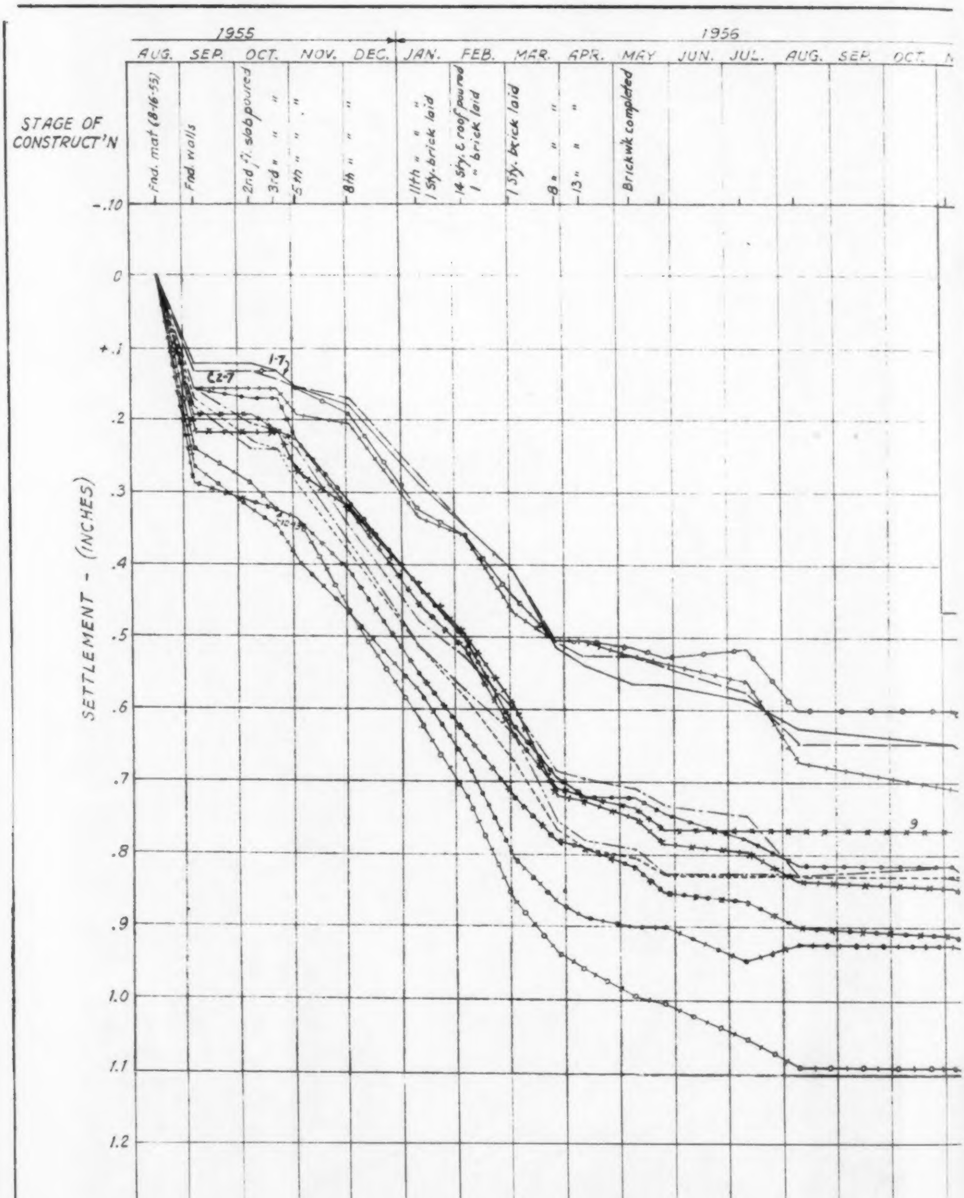


Figure 13


1955
1956
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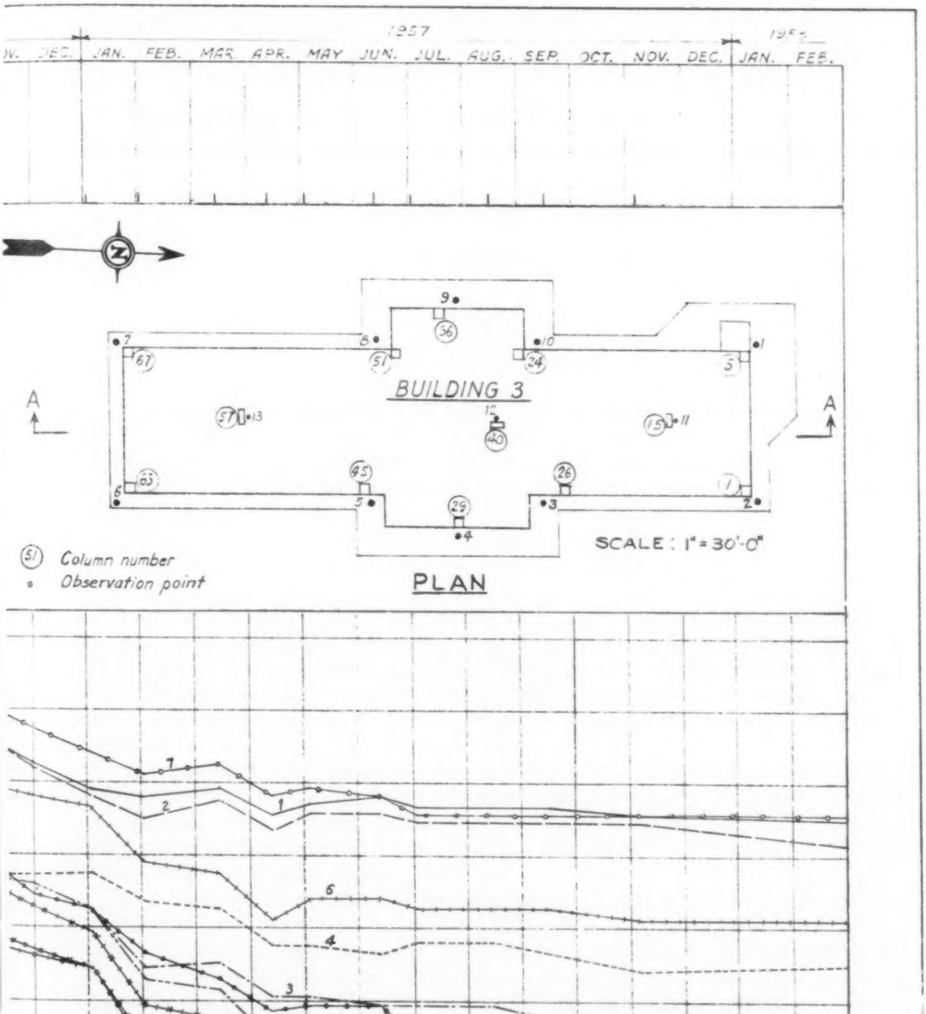
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BUILDING 3
A
A
SCALE: 1" = 30'-0"
(51) Column number
Observation point
PLAN

FIGURE 14

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VENTILATED BUILDING FOUNDATIONS IN GREENLAND[a]

Roger H. Williams,[1] F. ASCE

SYNOPSIS

This paper describes the ventilated foundation systems used in permafrost areas in Greenland. It includes discussion of those factors of heat transfer, moisture content, ground water conditions, and structural details which affected the designs as well as the siting, orientation, and maintenance problems involved.

Ventilated foundations are used in permafrost areas where materials, if thawed, lose their ability adequately to support the proposed structures. It is obvious if such a system is used, it must provide for the removal of heat from the soil in such a manner that no underlying soils which would lose their strength are thawed. Fig. I depicts one typical ventilated foundation construction.

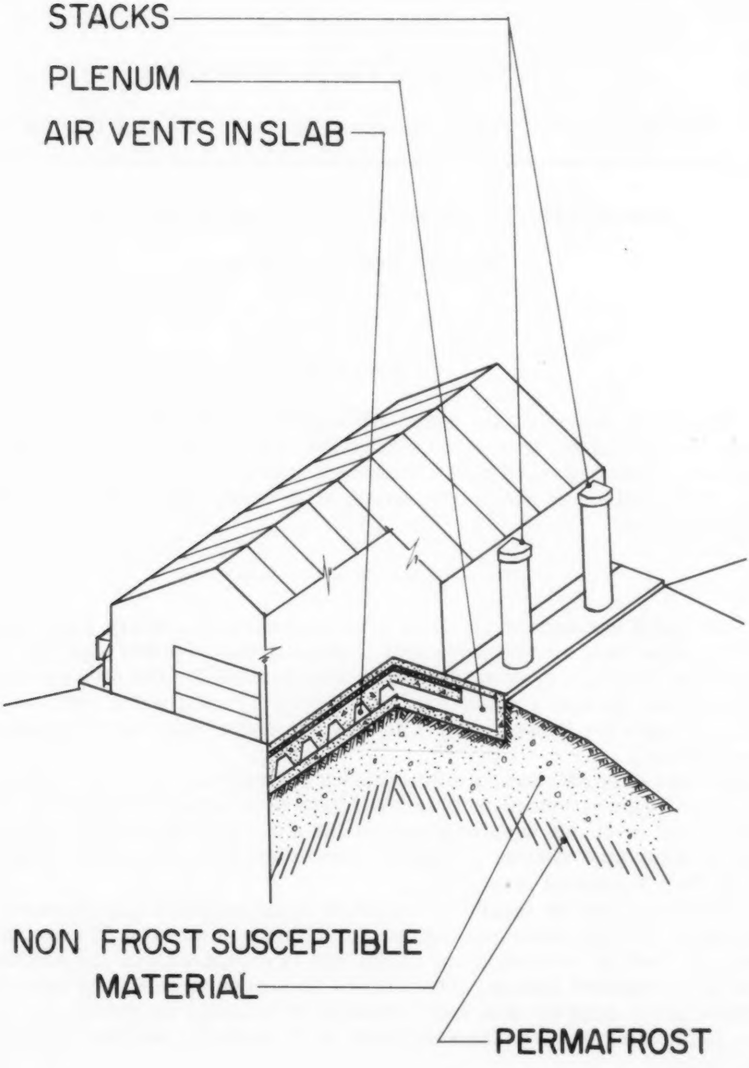
In areas of borderline or discontinuous permafrost, extreme caution in the use of this type structure must be exercised to prevent retrogression of the permafrost level into unsatisfactory materials. In these areas it is necessary to determine whether ventilated foundations are practicable or whether some other treatment is necessary.

At times it may be feasible to excavate some unsatisfactory material and replace it with non-frost-susceptible fill. This is a question of economics in which the cost of excavation and backfilling is compared with the additional cost of a ventilated system. This occurs when rock is relatively near the surface and it must be determined whether to excavate all the way to rock, thus eliminating the need for ventilation or to excavate part way and provide ventilation.

Note: Discussion open until February 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2142 is part of the copyrighted Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. CO 2, September, 1959.

a. Presented at the June, 1957, ASCE Convention in Buffalo, N. Y.

1. Engr.-in-Charge, Metcalf & Eddy and Alfred Hopkins & Associates, Architect-Engrs., Boston, Mass. and New York, N. Y.



TYPICAL CONSTRUCTION
Fig. I

The purpose of ventilated foundations for heated structures is to permit cold air to be circulated beneath the heated floor with the object of removing heat transmitted through the floor thus preventing it from entering the ground, and also during cold weather to remove heat from the ground thus maintaining satisfactory ground temperatures to preserve the permafrost.

Since all of our ventilated foundations are constructed on gravel pads, it might be well to consider at this point construction and purpose of this pad. The gravel pad is as its name connotes constructed of non-cohesive material which is non-frost-susceptible. The area of the pad is usually such that it will extend from 10 to 15 feet outside of the exterior foot line on all sides of the structure. It is constructed with extreme care to insure that the desired compaction is obtained to support the proposed structure without settlement that would jeopardize the structural integrity or the usefulness of the structure.

The thickness or depth of the gravel pad is designed to prevent thawing of any underlying material which, if thawed, would cause unacceptable foundation settlements. This does not mean that the pad is always thick enough to prevent thawing below its bottom surface since it is possible to have strata at considerable depth which have satisfactory load bearing qualities, but these in turn may be underlain by unsatisfactory materials. (Fig. II)

It is obvious then that the thickness of the pad is dependent upon the temperature to be maintained in the heated structure, the air-moving characteristics of the ventilated floor system, the freezing and thawing indexes, the heat absorption and transmission properties of the floor materials and the gravel pad materials, including their water contents.

An ideal gravel pad would be one completely saturated with water since the high specific heat of water would inhibit thaw penetration, hence requiring less thickness of pad to protect underlying materials. If such were possible, provisions would, of course, have to be made to prevent this water from entering the ventilating system where it might freeze and reduce the effectiveness of or entirely eliminate air movement. While a saturated pad as described above is highly desirable, it is not usually easily obtained using normal arctic construction methods. To insure continuous saturation it would be necessary to dike around the pad with some impervious material or to use some waterproof membrane to contain the water. The cost of such a system and the construction time involved would be such that it is considered more practical to use added depths of fill and consider only that moisture content that can be reasonably estimated to be held in the granular material by capillary action. It is evident from this discussion that fine granular material having high water retention characteristics is desirable for pad construction provided, of course, it is non-frost-susceptible.

We have seen that in certain respects moisture is advantageous in the design of pads for ventilated foundations. There are two ways in which the presence of water may be disadvantageous. The first of these concerns the layer of melt water which exists, in some cases, at the thaw line in the active zone as the thaw progresses downward from spring through summer. Since the materials in glacial deposits usually are far from uniform there may be a large variation in the depths of thaw below the surface in a given watershed. This is usually quite true in many relatively flat areas that are naturally picked for development and here even small variations may be important.

The variation in depth of thaw results in a water surface on top of the frozen material that may be quite dissimilar from the surface contours. This

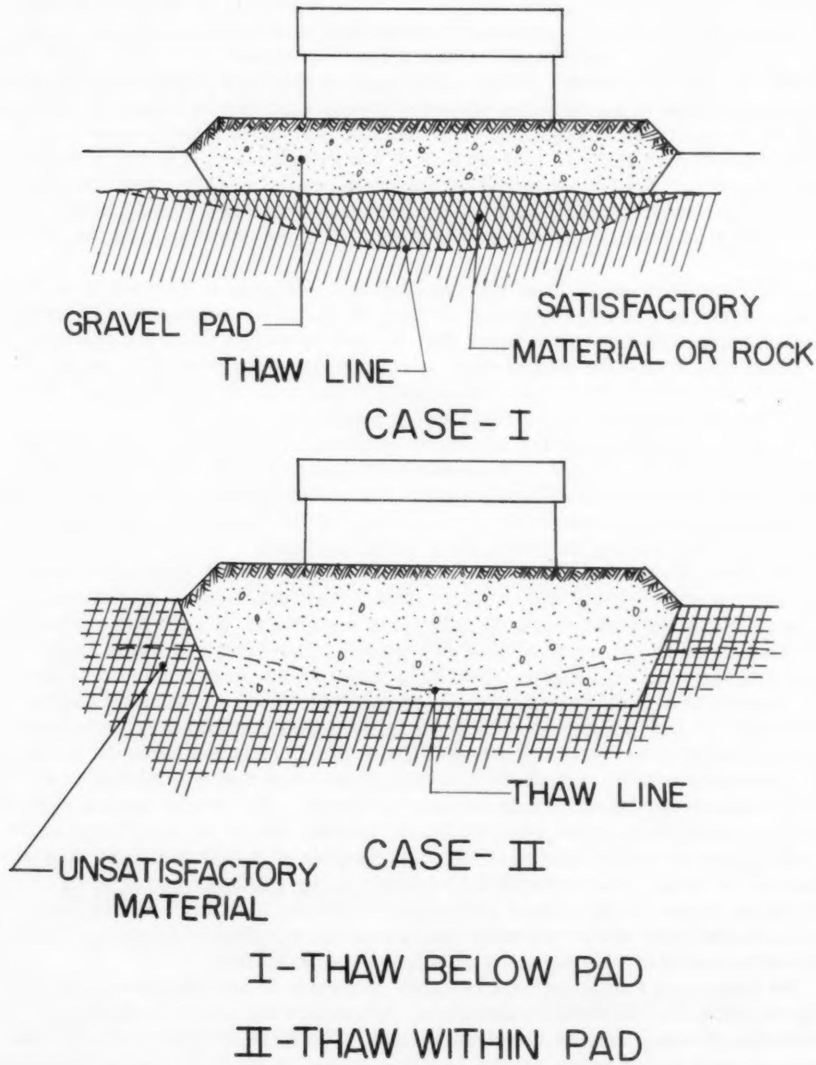

GRAVEL PAD
THAW LINE
SATISFACTORY
MATERIAL OR ROCK
CASE-I
THAW LINE
UNSATISFACTORY
MATERIAL
CASE-II
I-THAW BELOW PAD
II-THAW WITHIN PAD

Fig. II

dissimilarity is usually increased by the raising in some places and the lowering in others of the frost line by the construction of gravel pads and the excavation of unsuitable materials and replacement with soils of different thermal characteristics. Such artificial changes in the surface topography result in the creation of subsurface frozen dikes and troughs that may have a substantial effect upon the distribution and run-off of the subsurface water. The heat inherent in this water may have serious effects on subsurface materials if its flow is concentrated. Where such conditions might exist, provisions must be made to insure that flowing water is diverted from any area where thawing of the ground through which it flows would be detrimental to any foundation. The problems that this water, or water from any source, creates if permitted into the ventilating system ducts will be discussed below under maintenance matters.

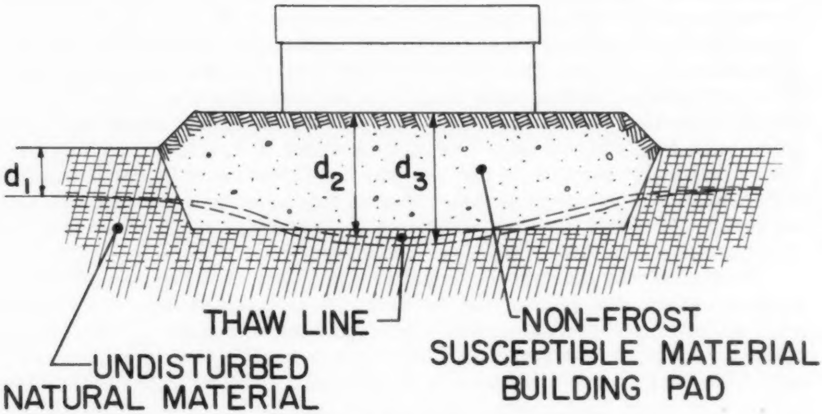
The second way that water can cause a problem is in the case of sub-permafrost or intra-permafrost aquifers. In areas of shallow discontinuous permafrost or permafrost in badly fissured rock it is possible that the thaw below a ventilated foundation may intercept an aquifer that is under pressure due to the back freeze of its course downstream from the site of thaw. Such a condition might exist since it is possible that the back freeze downstream where the aquifer might be nearer the surface and thus exposed (i.e., not under a heated building) would occur before back freeze under the structure where the maximum thaw could be deeper due to the heat of the building. If in this situation the aquifer upstream is also below the freeze line, water could flow upward and into the ventilating system and by freezing there cause trouble. These water courses are very hard to locate and, unless extensive subsurface data is available, it is difficult to predict their behavior. To the best of my knowledge this condition has not been encountered under any ventilated foundations in Greenland. It has however occurred in two non-ventilated slab-on-grade structures.

Summing up this discussion of the pad construction, we may say that its purpose is to support the structure above unsatisfactory materials that we must keep frozen, and that by its ability to absorb heat in the summer and release heat in the winter it is a very important part of any ventilated foundation system.

Extensive studies by the Corps of Engineers, U. S. Army, at the Arctic Construction and Frost Effects Laboratory (including the analysis of data obtained at Thule relative to subsurface temperatures during the years 1951-1953) have resulted in the establishment of standard procedures to determine the proper thickness of building pad knowing the other factors involved. These procedures are set forth in Chapter 6, Part XV, of the Corps of Engineers Engineering Manual, entitled "Arctic and Subarctic Construction, Calculation Method for the Determination of Depths of Freeze and Thaw in Soils." Figures III and IV show a typical building foundation and indicate the factors that must be considered in determining the depth of pad. They also show the effect of raising the building temperature.

Excessive depth of thaw at least may result in undesirable settlements and at most failures that may jeopardize the utility of the structure or cause its destruction.

Three types of ventilated floor systems have been used in Greenland. The first (Fig. V) and simplest has been utilized in small buildings not generally requiring motor vehicle or aircraft access. This system consists of a timber crib work placed on a gravel pad of sufficient thickness, with the building



CASE I

AIR THAWING INDEX..........1960 DEGREE DAYS

AIR FREEZING INDEX.........4920 DEGREE DAYS

SURFACE THAWING INDEX..........1175 DEGREE DAYS

FOR EACH LAYER OF UNDISTURBED NATURAL MATERIAL:

SOIL CLASSIFICATION.......................................SM

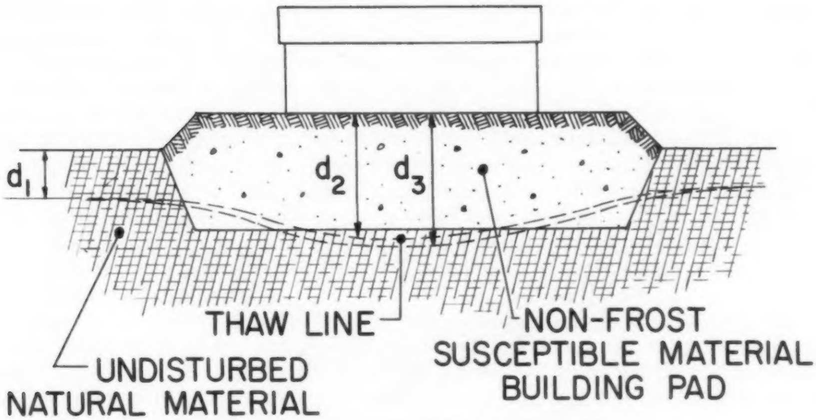
THICKNESS..1 FT

DRY UNIT WEIGHT......................97.6 LBS/CU FT

MOISTURE CONTENT..................21.8 PERCENT

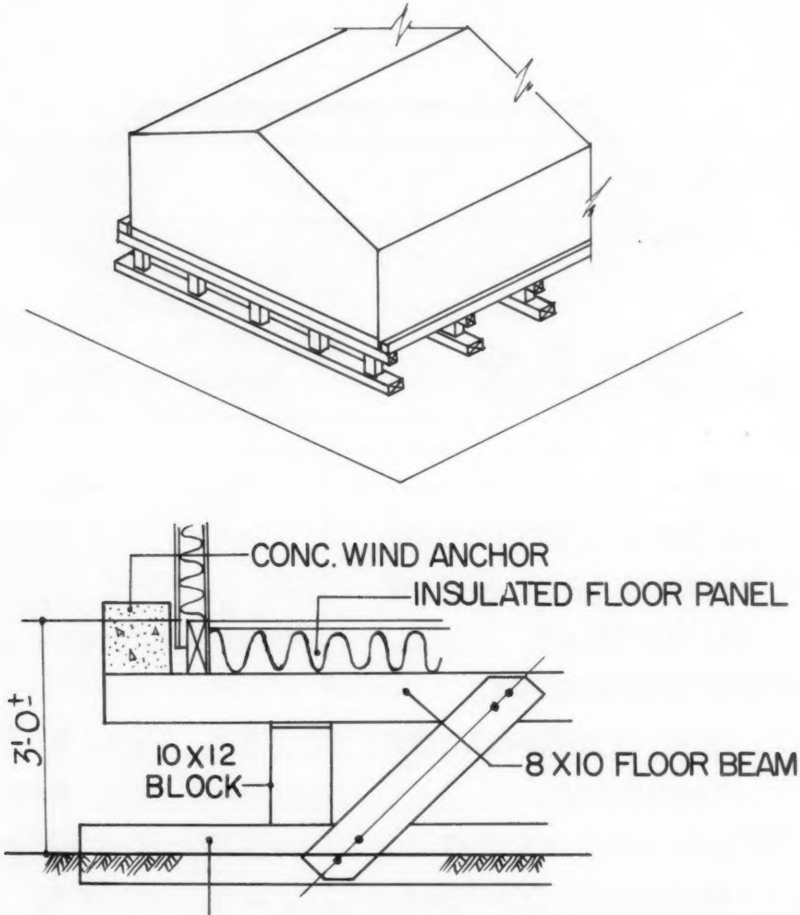
TOTAL DEPTH OF THAW (d_1)............................6 FT

Fig. III



CASE	II	III
BUILDING TEMPERATURE	65°F	85°F
THAWING INDEX BELOW FLOOR SLAB	1585 DEGREE DAYS	2500 DEGREE DAYS
FOR BUILDING PAD		
SOIL CLASSIFICATION	SP	SP
THICKNESS	8 FT	8 FT
DRY UNIT WEIGHT	140 LBS/CU FT	140 LBS/CU FT
MOISTURE CONTENT	4 %	4 %
FOR UNDISTURBED NATURAL MATERIAL: SAME DATA AS CASE I		
TOTAL DEPTH OF THAW	(d_2) 9.3 FT	(d_3) 10.4 FT

Fig. IV



CRIB TYPE FOUNDATION

Fig. V

placed on a crib approximately 3 feet above the surface of the gravel. This system provides ample space for air to circulate. One disadvantage is that it also permits warm air to circulate in the warm seasons.

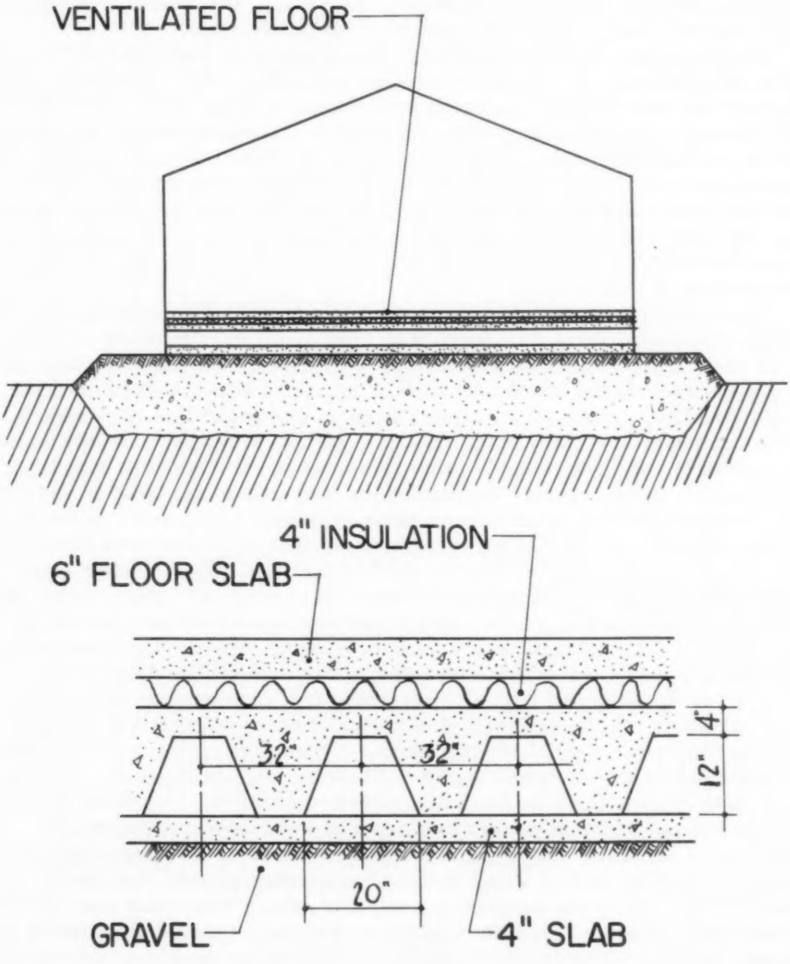
However, due to the fact that this system provides very efficient ventilation it is effective and, of course, relatively inexpensive. It is extremely satisfactory for light buildings in areas with a high freezing index and a low thawing index as long as snow is not permitted to accumulate in the crib space during the freezing season. Since the areas in which construction has taken place have relatively light snowfall and practically unidirectional winds during the freezing period, snow accumulation has not been a problem. By proper spacing and orientation of buildings, snow deposits can be controlled to accumulate only in areas where they will not substantially impair ventilated foundations of this type.

Structures placed on this type foundation generally have been prefabricated panel type single story structures with either load bearing walls or wood or light steel frames. These structures are designed to be capable of experiencing some differential settlement without incurring any structural damage or impairing their utility. Structures placed on this foundation in general have been limited to one-story buildings, 30 to 40 feet wide. Because the winds are unidirectional, the length of this structure is not limited by foundation ventilation considerations. By placing the long axis of the building parallel to the direction of wind, snow accumulation is limited to a deposit at the lee end of the building. Structures over two hundred feet long have been built. One two-story concrete Officers' Quarters has been built with the first floor elevated and supported on concrete columns. In general, buildings larger than those mentioned above, particularly those with loads heavier than are experienced in housing facilities, are more suitably supported on ventilated foundations of the second or third types, which now will be described.

The two systems are both slab-on-grade type foundations. In one (Fig. VI) the ventilation is provided through a series of ducts formed in a concrete slab by the use of metal floor pan forms. These ducts are placed 32 inches on centers and are 12 inches high and 20 inches wide at the base. The entire slab on the gravel pads consists of 4 inches of concrete upon which the pans are placed and concrete poured to a depth of 4 inches above top of pans. Over this 4 inches of cellular glas insulation is placed and finally the floor slab of concrete, usually 6 inches thick and reinforced with wire mesh, is constructed. Individual footings for columns extend below this slab into the gravel pad. In some cases the ventilation ducts are carried down below the normal level under thick slabs such as those used for generator foundations and truck lift piston enclosures.

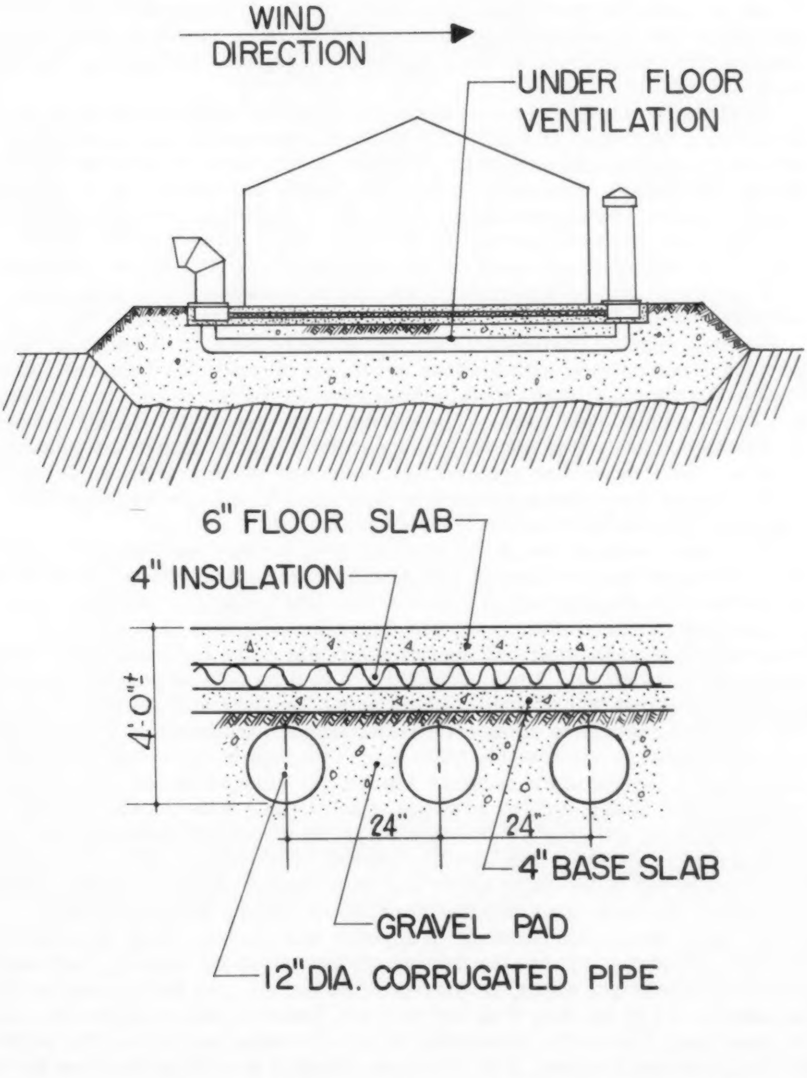
In the second type of slab on grade ventilated foundation system (Fig. VII) (which is the third type used in Greenland and the final one described herein) the ventilation is provided through corrugated metal pipes placed in the gravel pad. An insulated floor is constructed on top of the pad. These pipes are usually 12 inches in diameter and placed 24 inches on centers with invert 48 inches below top of floor slab. The pipes are manifolded at both ends and by a plenum and stacks are extended up the sides of the buildings as may be required.

The "pan" type ventilating system may be used with or without a plenum and stack system. For relatively small isolated buildings located in areas of little snow fall and where the building pad can be elevated a few feet above the surrounding level, no stacks or plenums may be necessary. In larger



PAN TYPE FOUNDATION

Fig. VI



VENTILATED PAD CONSTRUCTION

Fig. VII

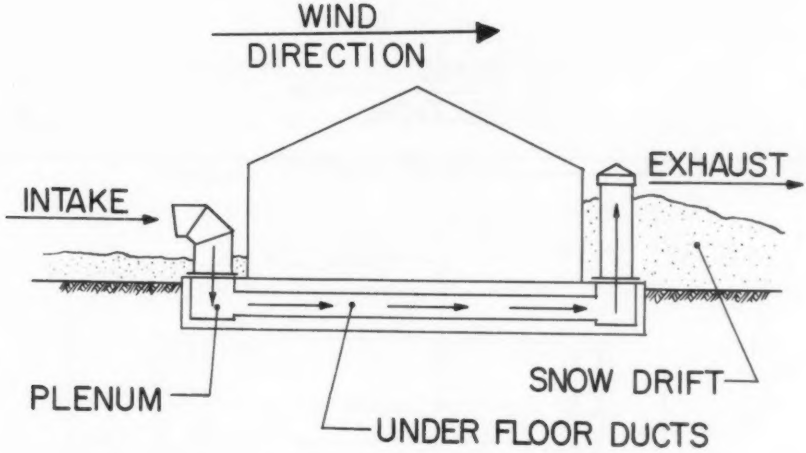
(Fig. VIII) structures where several structures of varying shapes and heights may be located in close proximity to each other, turbulence is possible resulting in irregular snow drifting patterns. In these cases where there is any possibility that the ducts might be clogged with snow, means of assuring air circulation in the winter, by the installation of plenums and stacks, are necessary.

Plenums or stacks are also required in large buildings to increase air flow by utilizing the "stack effect." This effect is obtained by making stacks on the windward side just tall enough to eliminate the entrance of snow and those on the lee side higher, usually up to the eave height, and always above leeward accumulations. Another advantage (Fig. IX) is gained by orienting large buildings with air ducts parallel to the wind. Since these buildings are usually for use as warehouses, shops and hangers, it permits the entrances to be placed on the sides parallel to the direction of the wind. Thus these sides are swept clear of snow, minimizing snow removal operations.

Plenums running continuously for the length of the side of buildings have been employed as have metal stacks set on top of manifolds from the underfloor ducts. Some of these metal stacks have 90 degree elbows on top similar to a ship's topside vent cowls. Thus, if for some reason the building cannot be oriented directly with the wind, the ventilator can be adjusted for maximum air flow. Both underfloor systems have dampers which are closed during the warm weather to minimize thawing in the subgrade and opened in the cold weather to permit back freeze.

Very little maintenance of the ventilating structures has been necessary on the elevated floor or the pan type slab on grade construction. Care must be exercised in the disposal of liquid wastes that leakage or spillage is not permitted to permeate the gravel pad, since the heat in such liquid may cause detrimental thawing and the moisture may enter the ventilating ducts, manifolds, or plenums. Since the ducts are kept as cold as possible provision should be made so that no water, water vapor, or snow will get into them. This includes seepage of subsurface water through the joints in the corrugated iron pipe (which is the nestable type) since this pipe is not watertight. Annual inspection at the end of the summer season, the removal of any obstructions to the full flow of air, and the removal of subsurface water in the thawed area beneath the building which might enter the ducts, are essential. During the past winter season a considerable amount of hoar frost has been observed to have collected in the ducts under buildings employing the corrugated metal pipe ducts. In some cases this has completely blocked the flow of air in several ducts under one building. It appears that the hoar frost is formed by the flow of cold dry air into the duct where heat from the building, and moisture from subsurface water, is absorbed into the air. As the air approaches the exhaust end of the duct it is cooled again, becomes super-saturated; and the water thus released is deposited on the cold metal surfaces. The reduction in cross-section area of the duct has resulted in reduced air flow which has retarded the back freeze. It was necessary that steps be taken immediately to reopen the affected ducts.

Future designs should provide for removal of water that may become trapped in the gravel surrounding the corrugated metal pipes, or it is possible that watertight pipes should be employed, or that the pipe system be eliminated in favor of the pan type system provided the necessary structural and thermal properties can be designed into the floor system. For all floor



TYPICAL UNDERFLOOR COOLING SYSTEM

Fig. VIII

loading requirements of the types of structures constructed in Greenland it is considered that the pan type ventilated floor is practical and economical. Its use is recommended; however it is still mandatory that provisions be made to exclude any water or water vapor from the pan type ducts, plenums, and stacks.

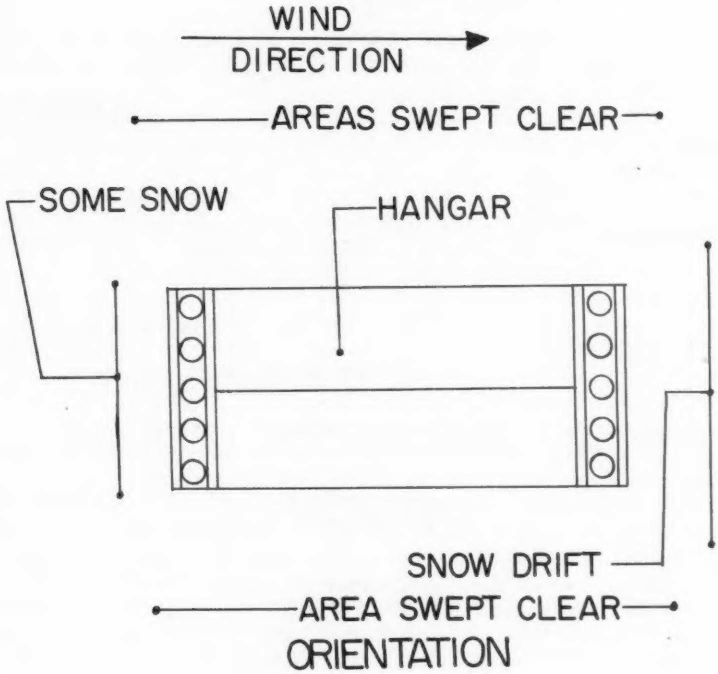

WIND
DIRECTION
AREAS SWEPT CLEAR
SOME SNOW
HANGAR
SNOW DRIFT
AREA SWEPT CLEAR
ORIENTATION

Fig. IX

Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

CONSTRUCTION OF THE COLUMBIA RIVER (PORTLAND-VANCOUVER) BRIDGES

Ivan D. Merchant,[1] M. ASCE

INTRODUCTION

The Columbia River forms the boundary between the States of Oregon and Washington for two hundred and fifty miles above its junction with the Pacific Ocean at Astoria, Oregon. The Columbia is one of the great rivers of this continent. It has a normal flow of 125,000 second feet, a low water flow of 35,000 second feet and the 1894 flood, the greatest in its history, had a discharge of 1,240,000 second feet.

At the present time, there are six bridge crossings of the Columbia in the lower two hundred and fifty miles of the river. The river crossing which will be described in this paper is between Portland, Oregon, and Vancouver, Washington, on the Pacific Highway, U. S. Route No. 99 or Highway No. 5 in the new Interstate Highway numbering system.

Description of Existing East Bridge

A brief description of the existing East Bridge is now in order to lay the background for the design and construction of the new West Bridge, which was opened to traffic on June 30, 1958.

The existing East Bridge was constructed in 1914-15 as part of a toll project sponsored by Clark County, Washington, and Multnomah County, Oregon. The toll project consisted of the 3,531' bridge across the Columbia River, a 1,500' embankment section across Hayden Island, a 11-span 1,138' plate girder bridge across Oregon Slough or North Portland Harbor, approximately two miles of embankment and a bridge across Columbia Slough.

Structures had a 38-foot roadway between curbs with a 4.5' sidewalk on the upstream side. This roadway carried two lines of interurban rail traffic and

Note: Discussion open until February 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. Paper 2143 is part of the copyrighted Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, Vol. 85, No. CO 2, September, 1959.

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two lanes of highway traffic. Interurban rail traffic was discontinued in 1935 and since that time the structures have been striped for four 9.5' vehicular traffic lanes. Average daily traffic is now in excess of 32,000 vehicles of which approximately 15% are trucks.

Since the original construction, the Oregon Slough Bridge has been revised by the addition of concrete spans overcrossing the Denver-Swift Road and an off-ramp to the same road.

Span arrangements of the main river crossing are, beginning at the north end; 1-50' steel girder span; 1-272' truss span and tower; a 272' vertical lift truss span; 1-272' truss span and tower, and 10-262' truss spans; all truss spans being through trusses as shown in Fig. 1.

The Oregon Slough Bridge was constructed as 10-101' and 1-114' plate girder spans. The 114'-plate girder span being designed for conversion into a lift span, if required by navigational development. The same span arrangements are used for the bridge widening.

Truss and girder span piers are the dumbbell type with the shafts connected by a heavy web wall. Pier loads are carried on untreated timber piling with a penetration of 50' to 80' below pier bases. At this point, the river bed is mostly sand, with some lenses of gravel, for depths in excess of 120'. Pier bases were constructed of tremie concrete inside of solid timber cribs. Details will be given later under the East Bridge reconstruction, on the existing piers and methods of strengthening.

West Bridge Construction

The volume of traffic being carried on the four-9.5' lanes of the East Bridge and the anticipated increase in traffic volume on the Interstate (Pacific) Highway required that additional facilities be provided.

The 1953 legislatures of Oregon and Washington passed legislation directing the Highway Departments of the two States and the Washington Toll Bridge Authority as the financial agent to prepare plans and specifications, sell bonds, construct the West Bridge, remodel the existing East Bridge, and build other required highway facilities as a toll project.

The total linear length of the toll project is 1.34 miles and is to be done under five contracts as follows:

Contract No. 1	Bridge Construction	$ 6,681,940
Contract No. 2	Grading and Paving	246,503
Contract No. 3	Bridge Construction (Remodeling of East Bridge)	2,993,995
Contract No. 4	Toll Plaza and Equipment	250,000
Contract No. 5	Lighting and Landscaping	130,000
Total estimated construction costs		$10,302,438

Additional costs for engineering, right of way, legal and financing and payments to the State of Washington as compensation for facilities in the toll

project entirely within the State of Oregon bring the total cost of the toll project to an estimated $14,500,000.

As of mid-April, 1959, Contracts No. 1 and 2 have been completed. Traffic was routed over the new West Bridge on the scheduled date of June 30, 1958. Contract No. 3 was awarded on May 28, 1958 and to date, all substructure pier work has been completed, work is well started on raising the truss spans, installation of new counterweight cables and anti-friction bearings and the removing of truss Span 13 and its replacement with concrete viaduct. Invitations to bidders on Contract No. 4 are out with the bid opening set for April 21. Contract No. 5 will be awarded in May or June. The completion date for all work on this project is December 31, 1959.

Upon completion of the entire project, tolls will be imposed. Toll schedules of 20 cents per passenger car, 40 cents for trucks, and 60 cents for a truck and trailer with a 25% reduction for commuter tickets have been established.

The above toll schedule was established on the basis of a maximum of 10 years for bond amortization.

On completion of the project, the East Bridge will carry three lanes of northbound traffic and the West Bridge three lanes of southbound traffic. The West Bridge will have a 40' roadway between curbs to conform to Interstate Standards with 1.5' set backs to guardrails and 2.0' to trusses.

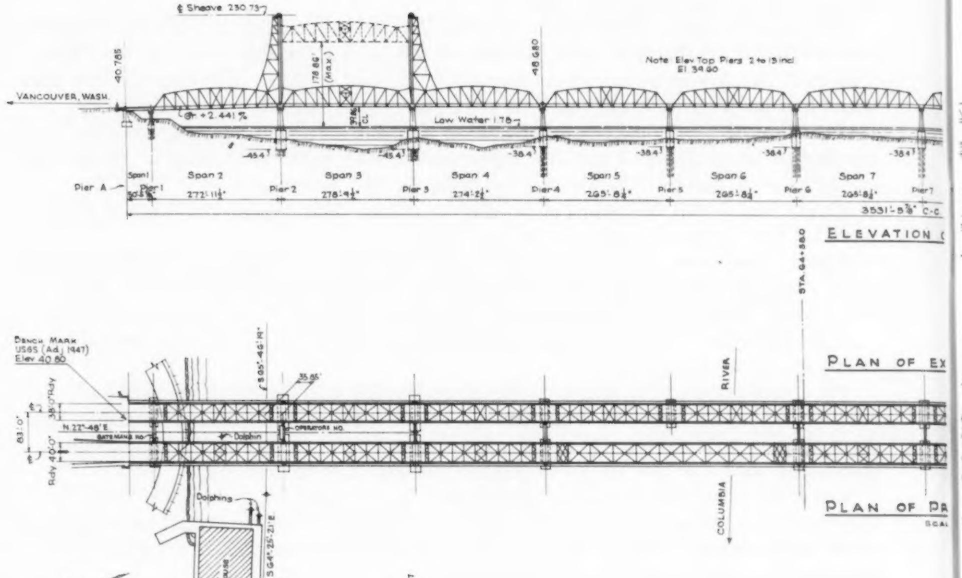
Because of the two lift span openings it was desirable to keep the two structures as close together as possible. A study of the existing and proposed piers indicated that 83' center to center of roadways was the least dimension possible to permit new pier construction.

Original plans were to duplicate span arrangements and grade of the West Bridge with the existing East Bridge. However, navigation interests objected to the twin lift spans in the main river channel adjacent to the dock facilities on the north bank of the river. The decision was finally reached to provide an additional low clearance navigation channel opposite Spans 5 and 6 of the East Bridge that would have a horizontal clearance of 510' and a vertical clearance at the center of 59'. This requirement is indicated in Fig. 1.

As noted, it requires replacing two-262' spans with one 530' truss and the raising of the grade line south of the lift span. Extensive remodeling of the existing East Bridge is also required to bring it to the contour of the new West Bridge. Although forced by navigation interests, the revision has an advantage to highway users as, on the basis of existing river traffic, approximately 85% of the lift span openings will be eliminated.

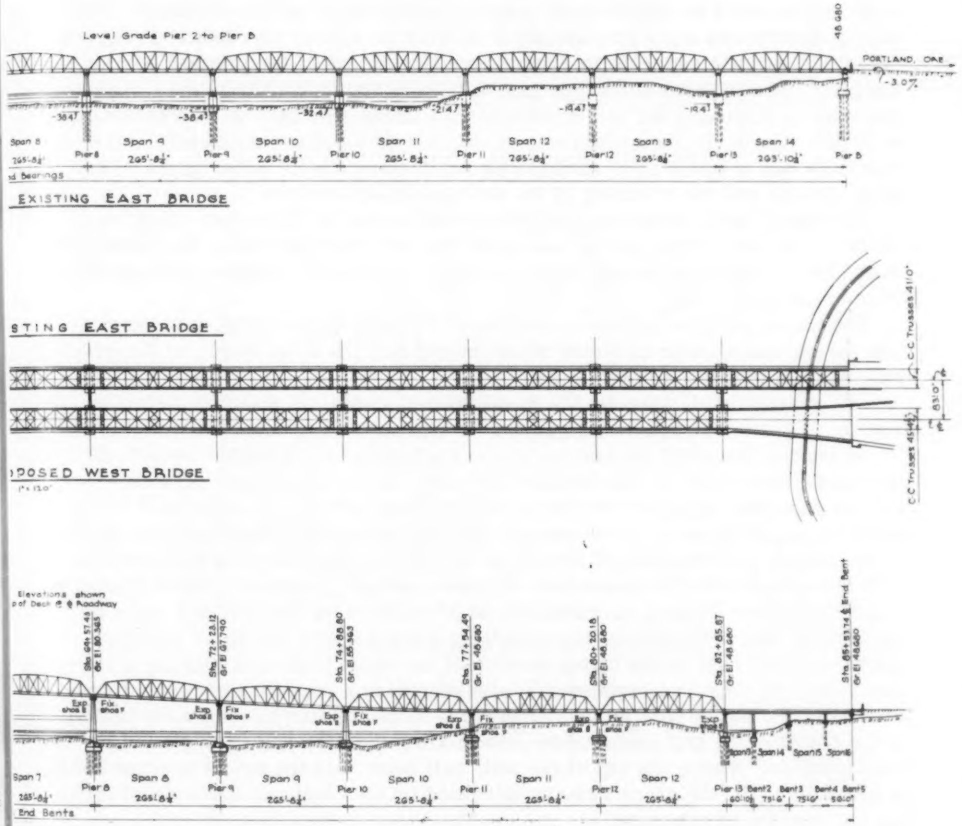
Application was made to the Corps of Engineers for reimbursement to the States, through the provisions of the Truman-Hobbs Act, for a portion of the revision costs to the East Bridge to provide the 520-foot low clearance navigation opening in Spans 5-6. An agreement between the States and the Corps of Engineers allocated the costs of the grade change, which required pier strengthening of five piers, and the removal and replacement of Spans 5-6, etc., equally to navigation and highway interests. This agreement has been ratified by the Congress and a token reimbursement made to the States of $40,000 of a total cost of $1,143,303 chargeable to navigation.

The Oregon Slough Bridge was to be widened with an additional 38' roadway for southbound traffic and separated from the existing roadway by a raised 4' median and with a 5' sidewalk. The 38' roadway was revised to 39' during construction and four spans were widened for a 12' deceleration lane to the Swift Ramp. With this change in roadway, Interstate Highway standards will be met for a deceleration lane to an off ramp.



Elevation of West Bridge (Revised) elevation

Fig. 1



elevation of East Bridge similar)

In the construction of the West Bridge and the widening of the Oregon Slough Bridge, it was decided to prepare alternate pier details. Alternate A design was for dumbbell type piers on timber foundation piling. These piers to be constructed in conventional manner within sheet pile cofferdams. Alternate B design was for a precast shell carried on timber foundation piling and filled with tremie concrete to Elevation + 10, the top of the precast portion of the pier. The precast shell type pier is similar to that used by the California Division of Highways for the Richmond-San Rafael Bridge and was developed by Ben C. Gerwick, Inc., contractors. On the basis of the successful contractor's bid, a substantial saving was realized on the 21 water piers of the West Bridge and the widening of the Oregon Slough Bridge.

The top of shaft of the precast piers was located at Elevation +10 after a study of the daily river levels indicated that with this elevation, the contractor would have a working season of ten months, in average seasons, between high water runoff periods.

Bottom of pier elevations varied from -45 adjacent to the ship channel to -19 for the main river crossing which meant that the total height of the precast pier section varied from 55' to 29'.

The precast shell pier for the main river crossing is shown in detail in Fig. 2.

As shown, the shell consists of three segments: (1) A bottom ring 7'-9" high and either a 37' or 32' outside diameter, (2) a conical section with a bottom diameter equal to that of the bottom ring and sloping in on an 8 in 12 batter to a top diameter 1'-4" larger than the cylindrical shaft section, and (3) a cylindrical shaft section of 13'-4" or 11'-8" outside diameter to Elevation +10, the variable height depending on base and shaft diameter. Shell thickness was 8" with 1-1/2" deep corrugations at 3" centers on the vertical faces of the bottom ring and shaft sections to form keyways with the filler concrete. Openings were cast in the upper section of the shaft to permit placing a precast beam serving as a support for, and becoming a part of, the connecting web wall. To aid in positioning, structural steel sighting towers were bolted to the bottom ring and removed by divers after the ring had been placed in final position. Above the top of the web wall beam and the top of precast shafts at Elevation +10, the piers were constructed by conventional methods of forming and placing of concrete.

The pier sections were cast in a central casting yard on the south bank and immediately west of Spans 11, 12, 13, and 14. A gantry crane was erected to service the casting yard as well as that portion of the structure southerly from Pier 11 not accessible to the contractor's floating equipment.

The various pier sections were cast in steel forms and were steam cured. Concrete with 1-1/2" maximum size aggregate and a 28-day breaking strength of 3300 p.s.i. was used except for the conical sections of the 37' base diameter piers. These sections were cast of a lightweight concrete weighing 115 lbs. per cubic foot to keep the weight within limits that could be handled by the contractor's floating equipment.

At this point, mention should be made of the walkway that was constructed on the downstream side of the East Bridge. In the precast shell type of pier construction, field engineering to assure accurate placement of piers, under water, is very important. To provide the contractor and the field engineering crew access to each pier area, without hindrance from traffic, a timber walkway 3' wide was cantilevered out from the existing trusses for the full length of the structure. This walkway was made of treated lumber except for a short

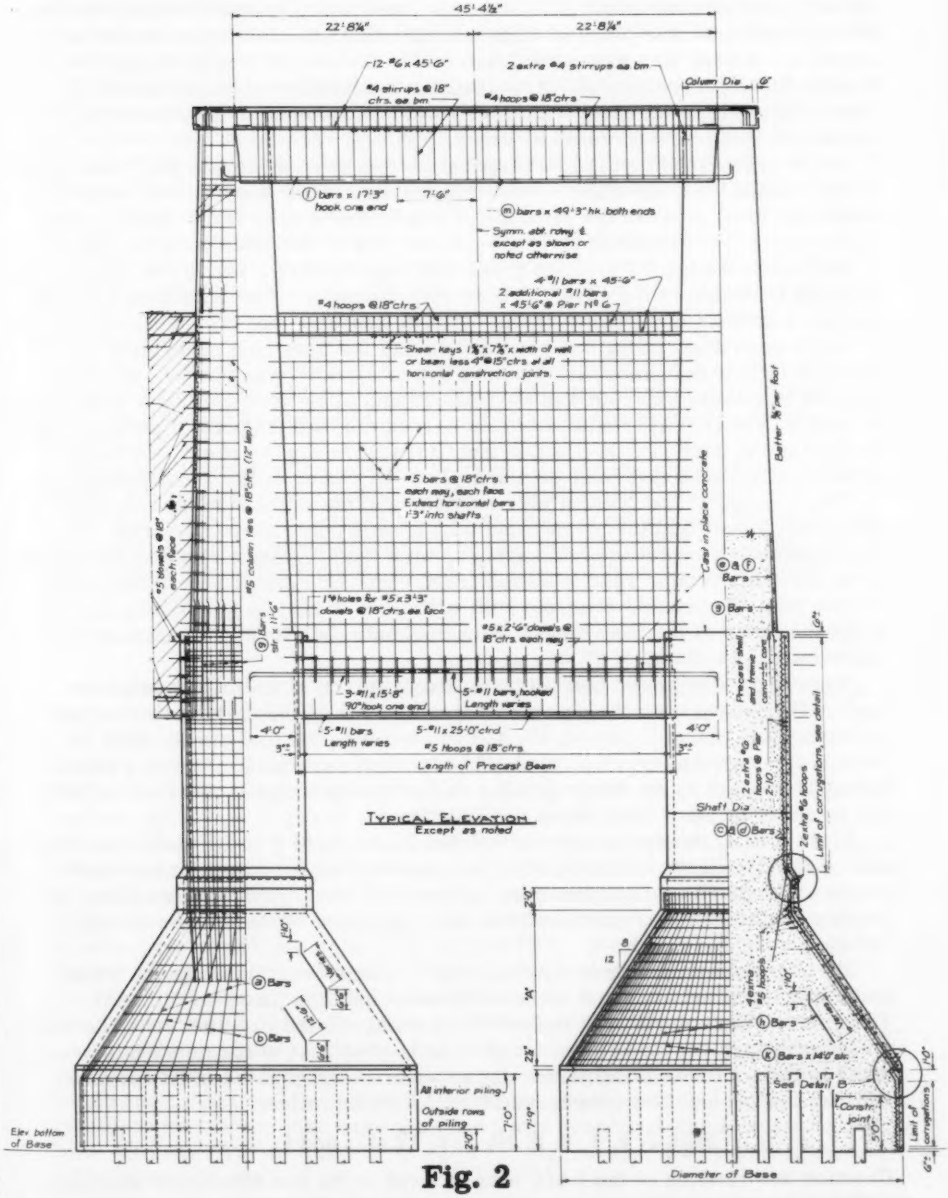

45'-4½"
22'-8¼"
22'-8¼"
12-#6 x 45'-6"
2 extra #4 stirrups ea bm
#4 stirrups @ 18" ctrs. ea bm
#4 hoops @ 18" ctrs
Column Dia
6"
(l) bars x 17'-3" hook one end
7'-6"
(m) bars x 49'-3" hk. both ends
Symm. abt. rdwy ℄ except as shown or noted otherwise
4-#11 bars x 45'-6"
2 additional #11 bars x 45'-6" @ Pier Nº 6
#4 hoops @ 18" ctrs
Shear keys 1⅜" x 7⅜" x width of wall or beam less 4" @ 15" ctrs at all horizontal construction joints
Batter ⅝" per foot
#5 bars @ 18" ctrs each way, each face. Extend horizontal bars 1'-3" into shafts
#5 column ties @ 18" ctrs (12" lap)
#5 dowels @ 18" each face
Cast in place concrete
(e) & (f) Bars
(g) Bars
1" holes for #5 x 3'-3" dowels @ 18" ctrs. ea. face
#5 x 2'-6" dowels @ 18" ctrs. each way
(g) Bars str. x 11'-6"
Precast shell and tremie concrete core
3-#11 x 15'-8" 90° hook one end
5-#11 bars, hooked Length varies
5-#11 bars Length varies
5-#11 x 25'-0" ctrd
#5 Hoops @ 18" ctrs
4'-0"
3"±
Length of Precast Beam
2 extra #6 hoops @ Pier 2-10
Limit of corrugations, see detail
TYPICAL ELEVATION
Except as noted
Shaft Dia
(c) & (d) Bars
2 extra #6 hoops
(a) Bars
(b) Bars
Varies
4 extra #5 hoops
(h) Bars
(k) Bars x 14'-0" slc.
See Detail B
All interior piling
Outside rows of piling
Constr. joint
Limit of corrugations
Elev. bottom of Base
Diameter of Base
7'-0"
2'-0"
5'-0"

Fig. 2

section each side of each pier where the walkway ramped down to approximate pier top level and is to be left in place as a permanent maintenance facility. At each pier an instrument platform was constructed by cantilevering out from the massive concrete piers to eliminate as much vibration from traffic as possible. A base line was established on the instrument platforms so that transit line intersections could be used for the location of piling and the precast bottom ring. No unusual difficulty was encountered in positioning piers within the required degree of accuracy.

In the pier assembly, the first operation was to excavate the pier base area 2' below pier base elevation. Timber foundation piling were driven to grade where possible or were cut off under water to grade by divers. Bottom ring supports were constructed by driving three sets of two piles each on 120° radial lines, cutting off to exact grade and capping with a section of H-beam with the H-beams centered at the base ring diameter. Specifications required the shaft to be constructed to an out of level tolerance not exceeding 1/2".

After foundation piling had been driven and the base ring accurately positioned to line and grade, 2' of coarse gravel backfill was placed. A five-foot lift of tremie concrete was next placed and allowed to develop a 3000 p.s.i. strength. This lift of tremie concrete served the dual purpose of permanently anchoring the base ring in position and of transferring, by shear, the weight of the precast cone and shaft sections yet to be placed to the foundation piling.

The remaining two precast pier sections and the precast webb wall beam were next placed and the piers filled with tremie concrete to Elevation +10. The reinforcing steel cages extending upward from the base ring and downward from the shaft section restricted the tremie pipe to a small area at the shaft center line. To provide concrete with sufficient fluidity to completely fill the large diameter of the base ring, a 7.5 sack concrete with 3/4" maximum size aggregate and a slump of 6" was used.

The contract provided that all work above the top of decks be completed and traffic routed over the new structures by June 30, 1958, with the further provision that Spans 1, 13, 14, 15, and 16 be completed by June 30, 1957 to permit approach roadwork to proceed under Contract No. 2. A very rigid schedule was set up by the contractor to coordinate the pier construction with the schedule of steel fabrication and erection.

Piers 1 to 4, inclusive, were completed first; Piers 6 to 10, inclusive, next with Piers 11, 12, and 13 completed last and used as fill in work when work on the river piers was not possible. During this time, pier work was also proceeding on the 10 water piers and the north abutment of the Oregon Slough Bridge.

The steel subcontractor's schedule was to begin erection of Span 2 truss and tower, proceed to Span 4 truss and tower, and then place the lift span. Erection began in April 1957 in Span 2. A change in the erection schedule was made necessary because it was found to be impractical to construct falsework bents in Span 4 in the flood period due to water height and the swift current. By spans, steel erection proceeded in the following order:

Span 2, 9, 4, 8, 3, 10, 7, 8, 12, 11, and 5.

Erection and riveting of the 5,500 tons of steel in the two structures was completed in March of 1958.

Specifications provided that the lift span could be erected in the raised position or that any impairment of navigation clearances should be subject to the approval of the District Engineer of the United States Army Engineers. The

contractor was permitted to impair the vertical clearance for a period not to exceed 45 days provided a vertical clearance 14' above the seated span was provided. The lift span, complete with machinery house and machinery, was erected on seven panels of truss Span No. 12 which, in turn, was supported by three barges.

The lift span was floated into place and seated 15' above the closed position on temporary steel columns. While in this position, counterweight cables and uphaul and downhaul cables were installed, the concrete deck and a balancing portion of the counterweights poured and auxiliary operating machinery put in service. With the lift span operable by auxiliary equipment the lift span and counterweights were completed in positions most favorable to the contractor's operations and machinery and electrical installations completed.

Truss steel was erected on falsework towers, three towers for the 262' spans and six towers for the 530' span. Jacks at each tower permitted exact adjustment to the true cambered position. Riveting followed closely behind steel erection.

Deck and sidewalk placing was completed in Spans 2 and 4 as soon as possible after placing the lift span so that machinery and electrical equipment could be installed and adjusted while placing concrete on the remainder of the truss spans.

During the period of truss steel erection, the girder spans of the Oregon Slough Bridge were being placed and deck and sidewalks poured.

In spite of delays occasioned by plan changes on the Oregon Slough Bridge which delayed steel fabrication and erection, the contractor completed all structural work on the West Bridge by the contract date of June 30, 1958.

East Bridge Reconstruction

As stated previously, an additional low clearance navigation channel was required by the permit issued by the U. S. Engineers. The substitution of one 530' span for the two 262' Spans 5 and 6 of the existing east bridge and the raised grade line presented some difficult engineering problems.

The additional loads imposed on the existing piers due to the long span and revised grade line required strengthening of Piers 4, 6, 7, 8, and 9. Pier 5 is to be removed to bottom of concrete. These piers were identical. The pier base was constructed of tremie concrete inside of solid 12" x 12" timber cribs 16' x 57' overall in plan and 35' deep, with a vertical 2" x 12" timber sheathing on the outside. The top of crib was at Elevation -3.4 with conventional dumbbell piers and web walls to Elevation 39.5. Ninety timber foundation piling per pier extend to within 5' of the top of crib and with penetrations into the river bed sand of up to 80' below base of piers. The revised grade line required raising 5.71' at Pier 4 to a maximum of 37.77' at Pier 7.

An analysis of the pile loads on the 90 piling of the existing piers under the larger vertical loads and the greater longitudinal forces due to increased pier height indicated that a prohibitive overstress would result. A design for the reinforcement of the pier base and shafts was developed which increased the base size from 13'-8" x 54'-8" to 32' x 73' and encased the dumbbell shafts with a concrete shell.

To simplify form work, the concrete shell encasement of the existing shafts was held constant at a thickness of 1', thus increasing the diameter of shafts 2' between Elevation +2 and +37 with the pier shaft extension above +37

constructed on the same batter. As the elevations at bottom of new pier cap varies, the shaft diameter varies; however, the difference in diameter is not great and all piers will have the same appearance. Below Elevation +2, the concrete build-up is identical for each pier except for the number of foundation piling and number of tie rods.

As noted from Fig. 3, the pier strengthening required a cofferdam encasing the existing pier. Additional foundation piling were driven and a seal concrete ring poured around the pier against the timber crib and extending under the concrete base.

At Pier 4, it was necessary to work with truss and tower Span 4 in place. For the remaining spans, specifications gave the contractor the option of doing required pier work with the spans in place or floating out the existing spans, completing pier work, and then replacing spans at the new elevation.

After dewatering the cofferdam, the remainder of the pier strengthening was completed in the dry. Above the top of the seal concrete ring the original timber crib was removed so that the concrete pier reinforcement could be poured against the existing concrete base. To provide the required horizontal tension, due to moment on the additional pier footing and shaft, 2-1/4" Ø low alloy steel rods are to be installed in 4" Ø holes drilled through the existing concrete base. Structural steel pedestals distribute the rod stress to the existing concrete base. After stressing the rods to approximately 60% of their yield value, the 4" hole and rod pedestals were pressure grouted and then encased in the footing ring concrete. As the rods were installed under a condition of no pile load, the rod reaction transferred from bearing of the rod pedestals on the existing concrete base to the new footing ring as the pile load was applied to the new footing ring from subsequently applied pier loads. Because of the limited space inside the cofferdam, it was necessary to install the tie rods in three sections with sleeve couplers. Essentially the rod ties are an application of prestressing of concrete. The balance of the pier encasement is mechanically anchored to the existing pier base with a system of split dowels with wedges and with the 1' thick shaft shell heavily hooped with the continuous hoops extending through drilled holes in the web wall.

As stated previously, the piers of the West Bridge and the East Bridge were to be connected with an extension of the pier web walls. The connecting web wall at Piers 4, 6, 7, 8, and 9 were constructed after all pier work has been completed and piers loaded with full superimposed dead load.

Superstructure work on the East Bridge involved placing new counterweight cables, sheaves, and sheave bearings; replacing Spans 5 and 6 with a 530' span; raising truss spans to new grade line; removing and replacing deck and sidewalk on Spans 7 and 8 to new vertical curve alignment; replacing Truss Span 14 with a 4-span concrete viaduct of varying roadway width. A very important feature of a twin bridge crossing is that traffic can be routed over one structure while repairs and alterations are being performed on the other structure without hindrance from traffic.

Tower Span 4 was originally constructed to a level grade but on the revised East Bridge this span is on a +2.39% grade.

The counterweight column and the truss have a fixed joint over Pier 3 with the column being carried on a 16" diameter pin and truss gusset plates rigidly attached to the bottom of the column and also bearing on the pin. To get the required Span 4 grade line, it was necessary to break the fixed joint at the truss Lo (L6) point and the counterweight column bracing at the U1 (U7) and

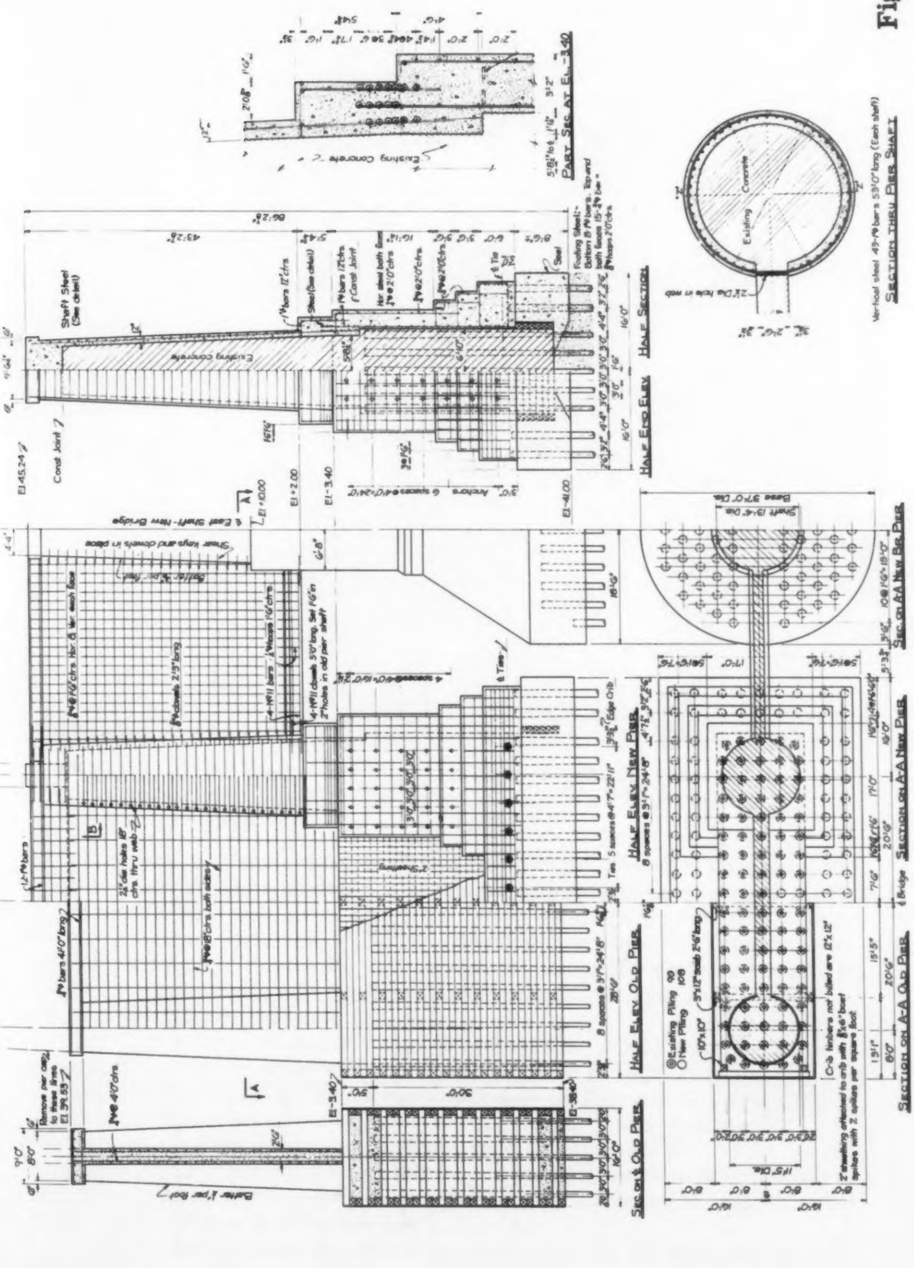

Sec on ℄ Old Pier
Half Elev. Old Pier
Half Elev. New Pier
Section on A-A Old Pier
Section on A-A New Pier
Sec. on A-A New Br. Pier
Half End Elev.
Half Section
Part Sec. at El. -3.40
Section thru Pier Shaft

Fig. 3

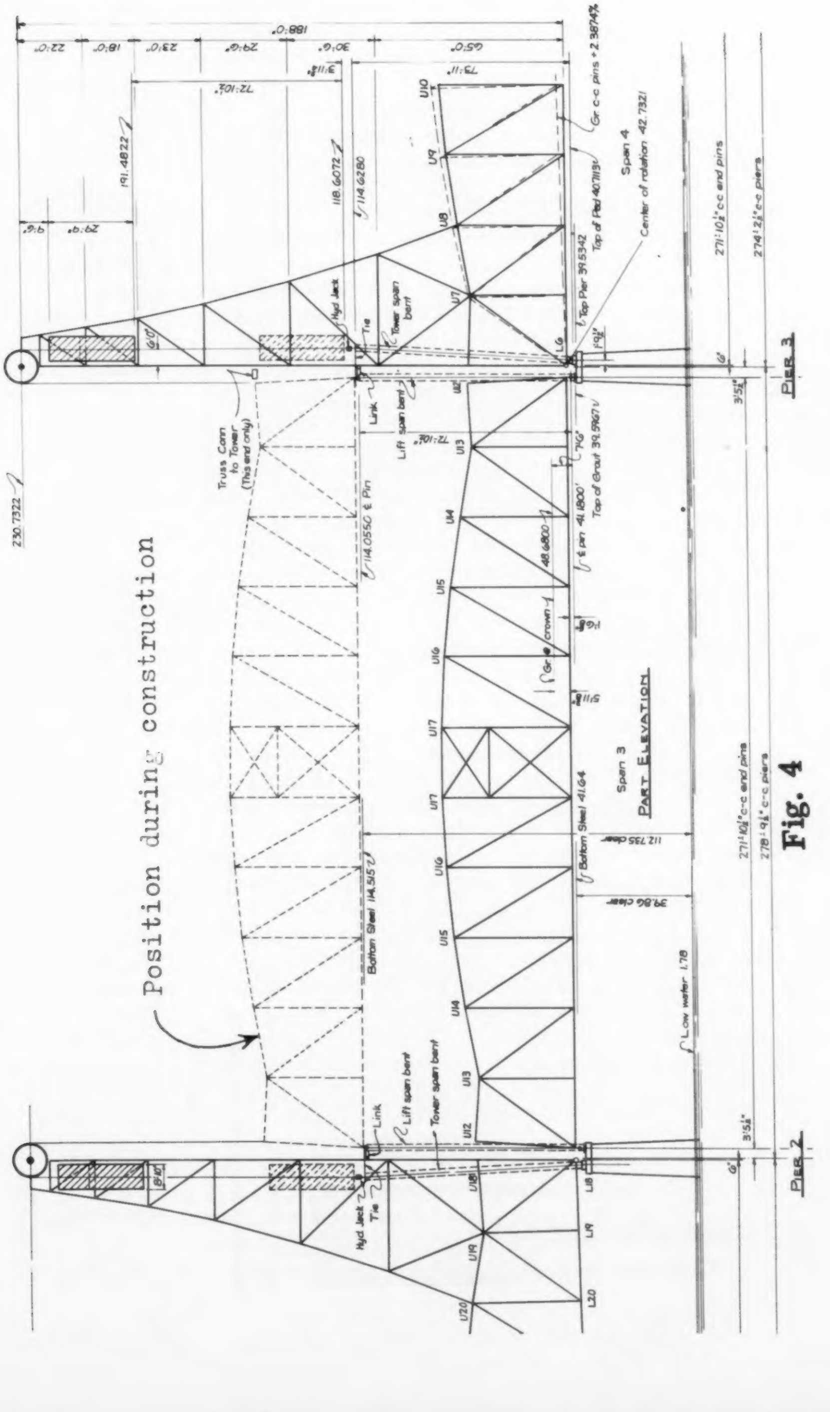

Position during construction
Truss Conn to Tower (This end only)
Span 3
PART ELEVATION
Span 4
Center of rotation 42.7321
Low water 1.78
Bottom Steel 114.515
Bottom Steel 41.64
112.735 clear
39.86 clear
Hyd Jack
Tie
Link
Lift span bent
Tower span bent
PIER 2
PIER 3
230.7322
191.4822
118.6072
114.6280
114.0550 ℄ Pin
Top Pier 39.5342
Top of Grout 39.5167
℄ pin 41.1800
48.6800
188'-0"
65'-0"
72'-10½"

Fig. 4

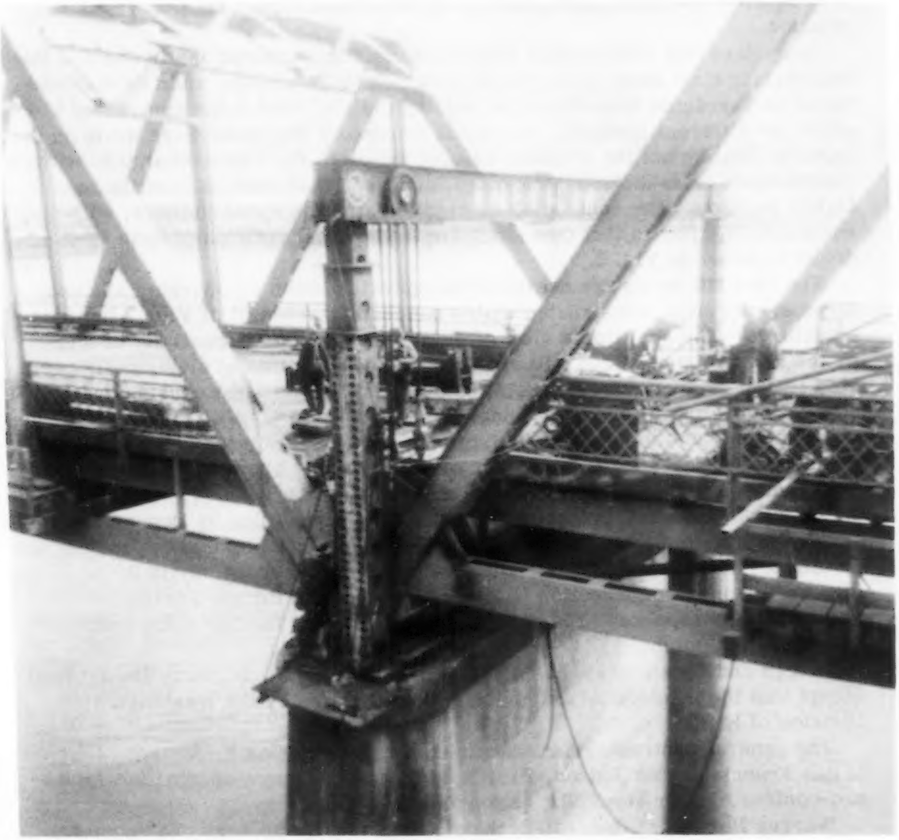


Fig. 5. Arrangement for lifting spans of the existing bridge. The telescoping columns are designed to contain a 275 ton jack with 5 in. lift.

U2 (U8) points and rotate the truss, about the 16" pin through an angle of 1° 22' at the same time holding the counterweight column in a vertical position.

As the lift span was out of operation during the placing of the new counterweight cables and bearings, a plan was developed in which the lift span was raised to midheight to provide 113' of vertical navigation clearance and to be used as the stabilizing unit for Pier 3 counterweight column and towers. General details are shown on Fig. 4.

There are two truss gusset plates framed inside of four thicknesses of column plates and bearing on the 16" pin. Because of local buckling of these six thicknesses of plates, it was not possible to remove all of the Lo joint rivets until the plates could be made to act as a unit on each side of the surfaces of rotation. This was accomplished by removing part of the rivets at a time, tapping the rivet holes and inserting cap screws to hold the two and four plate assemblies together on each side of the surfaces of rotation. Rotating the truss was done by jacking at Pier 4.

Complete details were developed for supporting the lift span and the tie backs to the counterweight columns, supporting the counterweight, breaking

the required truss joints and jacking equipment at Pier 4 for the Span 4 rotation.

In work of this kind certain final conditions are desired and it was felt that engineering time spent on a method by which those results could be obtained would be beneficial to contractors bidding the job, even if the contractor elected to use different methods. As stated previously the plans were made on the basis of floating out the trusses, raising the piers the required amount without interference from the superstructure, and floating the spans in at the new higher position. The contractor elected to raise the spans in place, with equipment similar to that developed for the vertical rotation of Span 4. A detail is shown in Fig. 5.

The twin lift spans are designed for operating from an operator's house, three stories high, constructed on the connecting web wall of Pier 2 between structures. The operator's view of the traffic streams is partially obscured by the truss members and will require manual operation of electrically operated traffic gates at Piers 1 and 4. Gatemans' houses were constructed on the connecting web walls between bridges at Piers 1 and 4. A system of interlocks prevents opening the span before traffic is cleared and gates closed. Machinery houses located at the center of the lift spans above the roadway house the span operating and auxiliary operating equipment.

All work on the toll project is scheduled for completion by December 31, 1959 at which time the six traffic lanes provided will eliminate the congestion on this portion of the Interstate Highway system. Other Columbia River crossings are planned in connection with a long range plan for the Portland-Vancouver metropolitan area when the traffic on this facility again reaches the saturation point.

Design and construction has been by the Oregon State Highway Department except that the mechanical and electrical design was by the Washington Division of Highways.

The general contractor for contract No. 1 was the Guy F. Atkinson Company of San Francisco with Judson, Pacific-Murphy of Emeryville, California, as sub-contractors for steel fabrication and erection.

Warren Northwest, Inc. of Portland, Oregon, were holders of Contract No. 2 for grading and paving. The General Construction Company of Portland are general contractors for Contract No. 3 with the American Bridge Company, subcontractors for steel fabrication and erection, raising of the truss spans and the dismantling of three truss spans.

Journal of the
CONSTRUCTION DIVISION
Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION

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ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: GRADUATES FOR WORK IN CONSTRUCTION[a]

Discussions by Paul F. Keim, Frank W. Stubbs, Jr., and Ellis Danner

PAUL F. KEIM,[1] F. ASCE.—The writer and Professor Day have discussed some of the elements included in this paper before. The principle point of his paper with which I thoroughly disagree is pointed out in the abstract of his paper, to wit: "... what one civil engineering educator believes should be included in a modernized under-graduate curriculum to particularly benefit construction industry, ..." I for one do not want an engineering curriculum to benefit the construction industry nor do I want a curriculum for anything but an education in its complete sense. Degree programs at any level directed toward any particular business, industry, or profession are not education and they are not the business of a university. Education is broadening and deepening, training is restrictive.

The training phases of education in basic techniques of science, math, surveying and engineering art are necessary. They are the base for the engineering superstructure. Training, however, for specifics of practice can only be useful when placed upon an adequate educational foundation. There is too little time as it is either in undergraduate or graduate curriculae to deal with detail when there are so many principles to be understood before detail can be meaningful. The training in specifics of practice are most logically the responsibility of the industry wherein the details of plant selection, estimating, cost accounting and other necessary arts can be most economically accomplished in the manner suitable to the individual company policy.

Construction men or practicing engineers who propose courses ending in degrees of Bachelors of Building Construction or bachelors of anything other than science or engineering are selling themselves, the students and the school short.

I agree that every facet of civil engineering should be covered in the curriculum but the curriculum should be directed at one goal, viz, a united construction industry and civil engineering profession. We professors, we industrial practitioners and the practicing civil engineers should not even think of the two as different entities but rather complementary parts of the same team.

I think that any program which tends in any way to suggest that civil engineering and construction should be divorced is bad. In fact, it is worse than bad because it would limit the horizons of men whose horizons need to be broadened in order that they can build the greatest structure possible for them on a stable foundation.

a. Proc. Paper 1955, February, 1959, by David A. Day.

1. Prof. of Civ. Eng., Univ. of Calif., Berkeley, Calif.

How good a construction engineer be if he does not understand the basic principles of transportation laws, rates and structure? Who is it operating in any sphere who can be most effective if he cannot write clearly in his reports and speak properly to enhance his public relations? This fractionating of civil engineering into options is strictly a disservice to both the construction industry and the engineering profession.

It is a prevalent idea that society in general and industry in particular should shift all the responsibility for the upcoming generation to the schools. Then when the schools seem to produce graduates which are not what was expected, the schools are at fault. I maintain that the schools should educate people so that they can and will continue to learn and to progress and should not train them for a particular job as if it were the end or an end. If industry or the profession cannot accept the training phases of their organization as one of the legitimate costs of their business then their organization is not good. Many smaller business men, contractors, and consulting engineers insist that they cannot afford a training program as can the larger groups. I maintain, however, that the business which cannot accept, as a cost of doing its work, the cost of perpetuating itself, has no reason for being. These people continue to insist that they want and should have some graduates from College who can begin to produce immediately upon graduation. Some of such producers may well be needed but for these immediate tasks why look to the college or to someone outside their organization to produce these short range personnel for them? I am not entirely sure that public schools should undertake this task. Why some industries think of immediate producers when what they, even the smaller contractors, need is the broader gauge man who can quickly learn the tasks of today yet with an eye on and interest in tomorrow is not understandable.

Now it appears that my disagreement with Professor Day is not complete because he finally points out, and I wholly agree, that the person who does not think of basic science as directly beneficial to him in construction "has taken a narrow, uncooperative and unimaginative point of view and has resorted to the convenience of hand books, rules of thumb and letting the carpenter or mechanic do it as best he can based on his experience. He has fallen into the trap of short sighted expediency for the sake of money and economy of time". This sort of activity is all that a specifically trained man can engage in, so therefore from whence is progress to stem? I suggest that everyone read that paragraph of Mr. Day's paper again and again and remember the words whenever the subject of education comes to their attention. If I might chide Mr. Day a bit I would suggest that he remember these words too when he is considering a curriculum for the Civil Engineering Department of the University of Denver.

FRANK W. STUBBS, Jr.,[1] F. ASCE.—Professor Day recognizes the difficulty of getting more material into the existing overcrowded curriculums in Civil Engineering and the apathy of many members of instructional staffs regarding the narrow and limited concept of Civil Engineering. Almost all the emphasis is and has been on the design. Many instructors fail to think in terms of a total project and seem to forget that each project has four major phases or stages.

1. Prof. of Civ. Eng., Purdue University, Lafayette, Ind.

The four stages are (1) conception or planning, (2) design, (3) construction, and (4) operation. These are the functions which constitute Civil Engineering and to say that Civil Engineering is just one of them is to indicate a complete misunderstanding of what modern Civil Engineering is. Planning is the step where the question "Will it pay" is answered and this is not to infer that the answer must always be in dollars and cents units, as important as they are. Design is the place where qualities of materials are selected and dimensions placed on the various elements. Construction makes a reality of the visions of design. And of course the whole purpose of the structure is to provide man with the fruits of its operation. All of these phases are engineering work. As the structures increase in size and complexity, specifications become tighter, schedules become shorter, and all are more and more technical in nature. The modern structures are possible because construction equipment and organizations have been developed to accomplish the work in a minimum of time and at the lowest possible cost.

Our educational program should not lose sight of the distinctive characteristics of Civil Engineering projects and never forget why they are different than manufactured items. A Civil Engineering project, and this does not exclude buildings, is generally one of a kind. The construction plant is moved to the site where transient crews are recruited and molded into an effective production organization. In some cases the assembly line moves from day to day. The work is done in the open and subject to the whims of Nature. The work is completed on schedule. The plant is dismantled and the organization torn apart, both to be reassembled at some future time at some unknown point. This is construction! No other industry attempts such a program.

If a young person is looking for a life work of thrills, it will be found in construction. One cannot visit the work at Glen Canyon, or other important projects, without sensing the challenge before the engineers, both contractors' and owners', building that great structure. Those looking for glamour will find it here. Here, too, is an area which can compete in its own right with nuclear engineering, electronics, rockets, and the like. But back to our educational programs.

There is a continuing increase in the demand that faculties be better prepared and this generally means an extended formal educational program to include the doctorate. This need is justified by the increased complexity of structures, processes, and materials and by a better understanding of them.

The advanced study frequently is done on a part-time basis so the length of time may be increased to six or eight years. The current programs usually entail twelve months per year. These young people are, therefore, devoid of practical experience when they complete the advanced work. At this stage they may be advanced to the rank of assistant professor. If we are to avoid having our staffs made up entirely of people whose life will have been spent in college halls, we must provide an opportunity for them to see what Civil Engineering is. There is no better place for this view than in construction.

These people can earn their salt even if taken into an organization for summer work only. What they lack in experience will be more than made up in their enthusiasm and willingness to work. Here is a place where our contractors can make a real contribution. A secondary advantage to the builder from such summer employment will be a better understanding of the builders' problems. This understanding will be exhibited in classroom problems and future designs may well have a clearer picture and a more realistic attitude toward tolerances.

It appears that there may be two educational approaches to construction. These may be considered as two stems, one is engineering and the other is management and who is to say that a combination of the two might not be the best. With the size and technical complexity of many modern projects one can not help but wonder if an engineering background is not highly desirable if indeed not necessary.

The revised undergraduate curriculum in Civil Engineering at Purdue offers some interesting possibilities. The curriculum has been changed from a series of option programs to a core curriculum (courses taken by all students in Civil Engineering) with technical and non-technical elective courses.

Fifteen credit (semester) hours of non-technical electives are provided in the second, third, and fourth years. Nine credit hours of technical electives are available in the fourth year. The core program contains one 2-credit course directed toward construction. Its title is "Construction Engineering and Management". This may be followed by a 3-credit elective course also directed toward construction. These five credits will replace the two 3-credit courses of the option program. In some cases a student may select a three credit project course where the work is in line with his interest. About nine credit hours of the non-technical electives may be taken in the economics, labor, and business. Under special circumstances it may be possible for a student to use six credits of the technical electives for advances courses in these areas. In addition to the above, the core program provides a strong background in mathematics, chemistry, physics, engineering sciences, structures, hydraulics, soil mechanics and foundations, materials, sanitary, transportation, and English and public speaking.

Studies are underway regarding a master's program in construction engineering.

ELLIS DANNER,[1] F. ASCE.—It is indeed unfortunate that engineering education in the construction field has lagged behind that in the design area. For it can truly be said that the success or failure of an engineering project depends to a large degree upon the quality of work and the economy achieved in the construction operations. Technical knowledge of construction procedures is equally as important to the designer as to the construction superintendent. For who can design a structure properly if he has not an adequate understanding of the costs and methods in its building?

Why has there been delay in the development of construction engineering education? The construction industry must shoulder its share of the responsibility for the lack of progress. For while the engineering educator must be farsighted and teach today what his students will need in practice ten or twenty years from now, he is nevertheless influenced by the demand for and the use made in practice of the things which he teaches. Engineering students reflect the demand from their future employers for the things which they study. If the construction industry emphasizes sufficiently strong its needs for technical and general knowledge of certain types, particularly of a fundamental nature, educators will adjust their programs to conform and more students will be led to these areas.

But the greatest need for development to aid construction engineering education is in the field of research. Those engineering areas which have grown the most rapidly and which attract the greater numbers and higher quality of both staff and students are generally those which have the most active

research programs. Knowledge must be attained before it can be taught. And the process of developing new knowledge is fascinating to both staff and students alike. Research requires financial support. This support usually comes from the governmental agencies and private industry most directly concerned with the problems at hand. The opportunities for research in construction are unlimited. Organized substantial financial support on a continuing basis will activate promising research programs in many engineering schools. And construction engineering education will progress along with these research programs.

In developing construction engineering education programs both educators and the construction industry must recognize that the formal education received in college is only a small portion of the total education that a person must acquire over a period of years to be a successful construction man. Decisions must be carefully made as to those things which can be most successfully learned in college and those things which can best be learned on the job. A brief but comprehensive picture of all the major parts of the construction business plus fundamental training in key specialized areas is the job for the college. The construction industry must not expect to get men out of college who have had training in all the diversified areas involved in the construction business. Four years or even five years of college time will not permit this. Cooperation between engineering educators and the construction industry should result in agreement as to what one will teach the prospective construction man and what the other will teach him. Both must recognize that this is the age of science and that the maximum use of scientific methods to supplement the art of construction is essential.

ENGINEERING EDUCATION AND CONSTRUCTION INDUSTRY: MODERN TRENDS IN CONSTRUCTION ENGINEERING EDUCATION[a]

Discussions by William Hersnleder and Henry G. Howard

WILLIAM HERSHLEDER,[1] M. ASCE.—Professor Schiffman's expressions of the trend in engineering education towards awarding a single degree in engineering science based on a greater concentration in fundamentals are astounding in their import. This program if carried out to its logical end would graduate students who after five years would have great difficulty entering design or construction without additional years spent acquiring some of the basic civil engineering tools which are now acquired in four or five years.

Unfortunately, Professor Schiffman does not give sufficient details of his projected general engineering curriculum, nor of its justification. One may gather however from his emphasis on "fundamentals" and the abandonment of "how to" or "hardware" courses that he would eliminate not only construction methods courses but to be consistent the greatest portion of such "how to" courses as surveying, drafting, highway engineering and even steel and concrete design courses because in fact these design courses consist of "how to" compute stresses and select members in accordance with code requirements.

If this be a correct interpretation of the trend, then this represents a definite swing away from the traditional college role of preparing the student for easy entry into civil engineering after five years and the construction industry and consulting offices had better prepare themselves for this condition.

On the other hand, if Professor Schiffman does not intend to abandon the usual design courses but only resist the entry of construction courses, then he fails, as unfortunately many engineering educators fail, to appreciate the definite need for the inclusion of construction principles in civil engineering education. The present exclusion is as logical as a medical education which teaches diagnosis but not cure. In objecting to the inclusion of construction education, Professor Schiffman states that construction is not a theoretical science. But neither are structural or hydraulic design. But both design and sound construction do require logical processes and the application of pure science. Furthermore design and construction are two phases of the act of creating a structure. Both phases are interdependent as it is not possible to design economically without a knowledge of construction.

Professor Schiffman further argues against the inclusion of construction training by stating that no four or five year course can "supply sufficiently all the factual knowledge necessary for absolute competence" in the areas involved in construction such as structural engineering, mechanical engineering, accounting and others. No one expects full competence. Not even the design

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a. Proc. Paper 1956, February, 1959, by Robert L. Schiffman.

1. Engr., Superior Concrete Accessories Corp., New York, N. Y.

offices expect full competence in structural design from the graduate. What the contractor or consultant desires from the graduate is an appreciation of the methods required to solve a specific problem, be it design or construction.

Professor Schiffman also states that a course in construction would be "a long look back". That should be no criticism. We learn from what has been done before, and most new developments in engineering as well as in the pure sciences are basically refinements or syntheses of what has come before.

It is true that some of the existing construction courses are less than inspiring. Too many such courses are akin to a stroll through an exhibit hall filled with pieces of construction equipment. There is a real need for systematizing principles of construction and preparing courses and texts which are more than mere compilations of manufacturer's design charts. But this will come in time.

Construction principles should preferably be taught in two parts: One part, which deals with the methods and the reasons structures are assembled in the way they are, should be included in the usual design courses to indicate how product standardization, methods of assembly and fabrication and available equipment determine the number and size of units which go to make up a structure. This is especially important in the design of precast concrete. The second part would consist of specific courses in construction administration and construction plant design and selection. These courses could be handled as electives and would be susceptible to increasing refinement for interested students.

At the end of this paper, Professor Schiffman at least recognizes the need for some sort of pre-job construction training. He recommends a "loop" course administered by the professional societies. It would be interesting to get an opinion on the feasibility of this plan from officers of the societies, but it is this writer's opinion that such a program would be too much of a burden for the society to administer at present. There is certainly an excellent challenge for task committees of the societies to systematize construction principles in a form similar to the outstanding ASCE publication, "Construction Cost Control", but the teaching of construction principles must revert back to the colleges which have been traditionally the best meeting place of the inquiring student, the dedicated tutor and the disinterested sponsor.

HENRY G. HOWARD,[1] F. ASCE.—The question of construction engineering education is growing in importance to the construction industry daily. Mr. Schiffman's ideas with regard to courses in construction subjects as a part of the civil engineering curriculum should have serious consideration. The adoption of the "loop" course program by the construction industry should also have serious consideration.

The rapid development taking place in the engineering profession today is equally reflected in the construction industry and the need for professional engineering in construction has been rapidly increasing in recent years. This fact is brought out constantly on the front cover of our professional society magazine "Civil Engineering" by the slogan used thereon, "The Magazine of Engineered Construction."

No one can refute the inestimable value of an engineering education. If we will think back to our graduation from college it is believed that all will agree

1. Chf. Bridge Engr., Southern Div., Michael Baker, Jr., Inc., Jackson, Miss.

that our degree in engineering was not the complete answer to our being a professional engineer. Practical experience to go along with the education was necessary then, is now and always will be.

Whether the young engineer graduate wants to go into construction, design, or eventually management, the value to him of practical experience both in construction in the field and design, including detailing and drafting in the office, can not be overstressed.

From the writer's own experience, the employment of engineering students during their summer vacations while in college either in the field on construction or in the office on drafting and detailing can be made valuable experience to them. The difficulty which engineering students seem to have in obtaining such employment would lead one to believe that sufficient consideration has not been given by management as to the benefit which they might gain from affording such employment. By some planning and supervision of a definite program along this line, it is believed the time necessary after graduation for training before the graduate is ready to take on responsibility could be shortened somewhat.

Another program relating to this subject which might well be given more consideration by the construction industry is the institution of the cooperative course plan which is now used by some industries. In this way, by alternating periods of education with periods of work in construction, the length of time needed after actual graduation to complete the "loop" course proposed by the author or to otherwise prepare the young engineer graduate for taking on responsibility might be shortened by several months or a year or more.

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: THE ENGINEERING PROFESSION IN CONSTRUCTION[a]

Discussion by Robert F. Borg

ROBERT F. BORG,[1] F. ASCE.—Mr. Corbetta has added fresh air on a subject which has long been in need of airing. Particularly cogent are his remarks regarding the concept of the combined architect and/or engineer and contractor not only designing but construction his own creations.

This field has been developed in this country up to this point only to a very limited degree and in the most part has been confined to industrial and factory construction of a repetitive or simplified nature.

There is no reason why the economies which are realized by the combination "package" of design and construction cannot be applied to a great many more fields than is presently being done.

The writer's own firm has had a modest amount of experience with this field and can report overwhelming success both from the point of view of client satisfaction and economy. This firm constructed as well as designed a college gymnasium under a "package plan" where the resulting savings helped to reduce the cost by approximately one third to one half of what a conventional school gymnasium costs in this area.

By drawing on the experience gained from twelve previous school jobs that were undertaken by the firm, we undertook the entire job from its inception to construction as one package which even included aid in the financing.

The King's College Gymnasium Auditorium, most of it 20 feet in clear interior height cost only 29.5¢ per cubic foot or $7.46 per square foot of area, including architectural and filing fees.

These unit prices are far below any costs recorded in this area for similar facilities. This company designed the building with construction cost as the prime consideration and economies were realized by the owner through such cost savers as prefabricated wood truss roof construction, concrete block exterior walls and the use of sturdy but inexpensive materials.

Low maintenance and high quality were still assured, however by using such quality items as first grade maple flooring and low cost oil fired hot air heat.

While this method may not be feasible for schools which are erected with public funds where the state education department rules require public competitive bidding, it nevertheless, could be used very extensively by privately owned schools or parochial schools.

As to the professional conduct of those concerned with the design it is pointed out that on the particular job cited above, there was a registered

a. Proc. Paper 1957, February, 1959, by Roger Corbetta.

1. Gen. Mgr., Kreisler-Borg Constr. Co., White Plains, N. Y.

architect retained by the firm for the architectural design and filing of the plans. This architect was able to act in accordance with the strictest standards of ethical professional conduct and in no way were any of his decisions influenced by any factors other than good design.

Mr. Corbetta is to be congratulated for bringing this subject to the forefront at this time and it is hoped by the writer that an open-minded attitude towards this type of project will be adopted by the profession.

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: CAMPUS TO CONSTRUCTION[a]

Discussion by Henry G. Howard

HENRY G. HOWARD,[1] F. ASCE.—Mr. Letoile's statement of the opposition of most educators to giving practical construction courses in our engineering colleges deserves serious consideration. It is believed that, by the proper approach, if the construction industry will keep pushing for such programs, they will eventually obtain some degree of success.

However, and the writer believes that Mr. Letoile will agree, there can be no substitute offered by college courses which can completely take the place of practical experience in the field.

The construction training program outlined in this paper by Mr. Letoile is excellent. The engineering student, who takes his education at all seriously will have three or, in some cases, four summer vacations during his college career. Here is the opportunity for the student to gain nine or twelve months of this experience before he graduates and many if not all such young men would welcome the opportunity if they could secure it, and the shorter time required for this training after graduation would be an advantage to the construction industry.

Of course, there is the argument that upon graduation the young engineer might accept employment with some other organization and his summers of training would be lost to the firm he worked with during these summer vacations. On the other hand, who can tell what valuable associations for both student and contractor might be formed?

The writer believes that, with an attractive and beneficial program, many of these summer employees would return for permanent employment upon their graduation.

It is believed that such opportunities for engineering students should at least be given some consideration and thought by the construction industry.

a. Proc. Paper 1958, February, 1959, by H. A. Letoile.

1. Chf. Bridge Engr., Southern Div., Michael Baker, Jr., Inc., Jackson, Miss.

ENGINEERING EDUCATION AND THE CONSTRUCTION INDUSTRY: WHAT THE INDUSTRY SHOULD HAVE FROM THE COLLEGES[a]

Discussions by Theodore B. Appel, Jr., Paul F. Keim, and Henry G. Howard

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THEODORE B. APPEL, Jr.,[1] F. ASCE.—The authors have given a splendid analysis of a situation which has come upon us in a gradual fashion so that, unfortunately, as of now many of us refuse to acknowledge its existence. The writer refers to the obligation of engineering colleges to provide means for civil engineering students, who so desire, to equip themselves to operate intelligently and efficiently at a professional and at an executive level in the construction industry. The authors point out the opposition which exists to the idea of wholeheartedly including qualified construction men among civil engineers and the difficulties of enlisting support from contractors for research by the colleges in the construction field.

A little over 100 years ago civil engineers were pre-eminent in the field of engineering. Since then one group after another has seen fit to dissociate themselves from ASCE and to establish new professions and societies. One cannot avoid wondering whether or not much of this has come about because some of our predecessors lacked vision. Will we witness yet another division? The engineering colleges can help prevent this were they to provide adequate construction courses, as some appear to be doing, within the framework of their departments of civil engineering where it undoubtedly belongs.

In their paper the authors mention the reluctance of engineering educators "to provide training in the practical and business side of engineering". In the writer's opinion this is extremely regrettable. Instruction in the basic sciences, the humanities and in professional subjects we must have, but that is not all. Witness the training given to dental and medical students while in college. Compare the medical school graduate as he approaches his internship with autopsies and clinical service behind him and the engineering student with little or no "hardware" or business courses when he arrives on his first construction job. Admittedly it is 7 or 8 years college against 4. The conclusion could be that Stanford's 5th year is a step in the right direction.

The fundamental function of colleges is to teach. It is their obligation to their alumni, to the voters if they are tax supported, and to society as a whole to teach those things which will fit our young men and young women for the profession or occupation of their choosing. It would appear that this fundamental obligation is being overlooked. There should be no question as to whether the engineering college or the contractor should do the job. It is presumptious for those of us who are not educators to think we can do a better job than they. Education is their specialty, their main activity, not a side line.

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a. Proc. Paper 1959, February, 1959, by C. H. Oglesby and John Fondahl.

1. Chf. Engr., The C. S. Johnson Co., Champaign, Ill.

The writer wishes that the authors had been more specific as to the type of research which is required to sustain a proper program of instruction in the field of construction. There is much research which needs to be done but which is not suitable for engineering college staffs to undertake. The problem of securing proper research contracts is one for which there appears to be no easy solution. It is not likely that contractors will rush forward to fill the vacuum. It may be that the colleges will have to bide their time, to establish their competence to teach construction and to educate the contractors on the benefits to all of suitable research programs. In this respect the colleges may have to "lift themselves up by their own boot straps".

Contractors could materially assist education for the construction industry were they to make provision for "sabbatical summers" for the lesser informed engineering college staff members.

PAUL F. KEIM,[1] F. ASCE.—Professors Oglesby and Fondahl are right in saying that in many cases the problems encountered by engineers in contractors' organizations are "equal in difficulties if not more difficult than those of the design engineers who developed the original plans for the project". I also concur witn the statement "Again, the design of contractors plant often calls for skills from every area of the Civil Engineers education, including structures, hydraulics, soil mechanics, highways, electrical engineering and thermodynamics".

If the above is so, then the contractors need full fledged Civil Engineers for their organizations from office to field in all areas of work and responsibility. To expect engineering graduates, however, to be able to accept responsible positions in any company without a period of apprenticeship with the company for which he will eventually accept this responsibility is asking too much of the men and of their colleges. This I say without any modification whatsoever as to the time the graduates have been in college or to the curriculum pursued. The college can give the education in principles and in detail, if there is time, covering the construction business but, in my judgment, the best, if not the only, contribution the civil engineering departments can make to the construction industry is to educate civil engineers.

Certainly the construction industry offers a feeling of permanence and belonging, it has financial incentives, and in it there is a wide variety of problems requiring every phase of education, so why not educate the students in universities and train them in industry. So much is said about what civil engineering can do for construction and many things have been suggested that construction can do for the universities and colleges and many of the latter are important. They are important but only corollary to the fundamental thing which industry can do, namely, accept as a legitimate cost of doing business the apprenticeship period, the training phase, or whatever else you wish to call that period after graduation in which we must learn the ways of our chosen company before production commensurate with the potential is possible.

Some say that certain detail given in a fifth or sixth year can shorten this hiatus but my experience has not confirmed that it can be shortened by extended schooling, that is, if you wish to have leaders rather than technicians. This leads me to the point where I wish to confute and reverse the following statement, "In a broader sense, civil engineering as a profession will gain far

1. Prof. of Civ. Eng., Univ. of Calif., Berkeley, Calif.

more than it loses by strengthening its ties with construction". This may be true but in this day of extreme competition for men the construction industry can lose much more than civil engineering if it does not recognize civil engineering for its intrinsic value to the industry.

Subject matter is important, but I repeat that universities are not the place to train men specifically for any job or for an industry or segment thereof. I do not mean that any area shall be ignored but there is only time to paint the broad picture in principles of action, not in any single detail of the picture. At the University of California, Berkeley, there is a chance for interested students to take many courses in business administration and economics which give them an idea of the business and management and money world. At the same time all civil engineers take courses in engineering economy and in contracts and specifications. Many others than those required to do so take a course in construction engineering, which gives them a conception of selection of plant, material, and equipment, and the principles of organization management. If construction industries will continue as they are, becoming more willing to use our nominal four-year student graduates in a training program within the industry we are well on our way to this integration of civil engineering and construction which all of us want, in fact need, for the best development of both.

HENRY G. HOWARD,[1] F. ASCE.—The writer heartily agrees with Messrs. Oglesby and Fondahl that research by the colleges and universities can make a real contribution to the construction industry. What is necessary is for the construction industry and colleges and universities to get together with the spirit and determination to learn and understand each others needs and problems and what each can contribute toward solving these needs and problems. With such a purpose in mind it is believed that these two parties could jointly reap great benefits.

The writer cannot agree with the construction executive that if research were to be carried out, it should be supported by the government. The government is now overloaded with functions which are not related to government with a tax load on the population that is approaching the unbearable. Even with the present tax load, we can not pay off our national debt. It is, therefore, the writer's conviction that such a program should not be added to the government load.

It also seems to the writer that the discount or refusal to give credit for experience gained in the construction field toward professional registration is taking an excessively narrow view of professional engineering. It is not the intent to in any way give the impression that the requirements for registration as a professional engineer should be made more lenient, but it is firmly believed that construction experience should be given due consideration. It is the opinion of the writer, in agreement with the authors of this paper, that there is no reason for not examining both design and construction experience at their face value.

There have been too many serious accidents on construction projects and failures of structures in the past few years. Could it be possible that some of these might have been averted if there had been registered professional engineers in the construction organization?

1. Chf. Bridge Engr., Southern Div., Michael Baker, Jr., Inc., Jackson, Miss.

In these days of rapid development of new design procedures and methods of construction, with ultimate design and limit design and all the rest, it seems as though the "mere execution" of the designers work requires the services of a professional engineer who understands the design phase as well as the construction.

Several states now require contractors to be licensed in order to do business in their state. Perhaps it might not be out of line that these contractors be required to have in their employ registered professional engineers for the execution of certain appropriate phases of their work.

Taken all together, the writer can still see the possibility for much improvement in relations between the construction industry, professional engineers, and our engineering schools.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1859 is identified as 1859 (HY7) which indicates that the paper is contained in the seventh issue of the Journal of the Hydraulics Division during 1958.

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FEBRUARY: 1933(HY2), 1934(HY2), 1935(HY2), 1936(SM1), 1937(SM1), 1938(ST2), 1939(ST2), 1940(ST2), 1941(ST2), 1942(ST2), 1943(ST2), 1944(ST2), 1945(HY2), 1946(PO1), 1947(PO1), 1948(PO1), 1949(PO1), 1950(HY2)[c], 1951(SM1)[c], 1952(ST2)[c], 1953(PO1)[c], 1954(CO1), 1955(CO1), 1956(CO1), 1957(CO1), 1958(CO1), 1959(CO1).

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APRIL: 1990(EM2), 1991(EM2), 1992(EM2), 1993(HW2), 1994(HY4), 1995(HY4), 1996(HY4), 1997(HY4), 1998 (SM2), 1999(SM2), 2000(SM2), 2001(SM2), 2002(ST4), 2003(ST4), 2004(ST4), 2005(ST4), 2006(PO2), 2007 (HW2)[c], 2008(EM2)[c], 2009(ST4)[c], 2010(SM2)[c], 2011(SM2)[c], 2012(HY4)[c], 2013(PO2)[c].

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JULY: 2079(HY7), 2080(HY7), 2081(HY7), 2082(HY7), 2083(HY7), 2084(HY7), 2085(HY7), 2086(SA4), 2087 (SA4), 2088(SA4), 2089(SA4), 2090(SA4), 2091(EM3), 2092(EM3), 2093(EM3), 2094(EM3), 2095(EM3), 2096 (EM3), 2097(HY7)[c], 2098(SA4)[c], 2099(EM3)[c], 2100(AT3), 2101(AT3), 2102(AT3), 2103(AT3), 2104(AT3), 2105(AT3), 2106(AT3), 2107(AT3), 2108(AT3), 2109(AT3), 2110(AT3), 2111(AT3), 2112(AT3), 2113(AT3), 2114(AT3), 2115(AT3), 2116(AT3), 2117(AT3), 2118(AT3), 2119(AT3), 2120(AT3), 2121(AT3), 2122(AT3), 2123(AT3), 2124(AT3), 2125(AT3).

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c. Discussion of several papers, grouped by divisions.

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